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*Printed or made in Great Britain
by Watts & Co. Stationers & Printers, Fleet Street,
London, E.C. 4*

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GLOSSARY

ALUMINA : animal without shell (*ammonia*)
ARTICHOKEANS : the evolution (*growth*) of
 man (*anthropos*)
ANTHROPOLOGY : the science of man
ARLITE : (in compounds) the first or typical
 — as, archyretula, archy-gastrula, etc.

ATLANTA : the science of the genera of life
 (*atlas*)

BIOLITE : (in compounds) pertaining to the
 early embryo (*biotic* = a body);
 hence —

Bioblastema, skin (*derma*) or covering
 layer of the embryo

Bioblastema : the embryo as the
 hollow sphere stage

Bioblastema : same as preceding

Epiblast : The outer layer of the
 embryo (*epiblastema*)

Epiblast, the inner layer of the
 embryo (*epiblastema*)

Epiblast : pertaining to the gill-
 (*epiblast*)

Epiblast : (in compounds) pertaining to the
 nucleus (*epiblast*), hence, —

Epiblastema, the movement of the
 nucleus

Epiblastema : division of the nucleus

Epiblastema, the matter of the nucleus

EPITHELIUM, see under **EPITHELIUM**

EPITHELIUM AND EPITHELIUM, animals with a
 dorsal chord or back-bone

EPITHELIUM AND EPITHELIUM, the body cavity in the
 embryo; hence, —

Epithelium : animals without a body-
 cavity

Epithelium : animals with a body-
 cavity

Epithelium, formation of the body-
 cavity

EPITHELIUM : (in compounds) pertaining to the
 cell (*epithel*); hence, —

Epithelium, the nucleus of the cell

Cytoid : cell-like bodies, imperfect
 cells

Cytoid, the matter of the body of
 the cell

Cytoid : the body (*cyto*) of the cell

CYTOTOXIC : abnormal retention of the
 tricholes in the body

DEVELOPMENT : see **PLATE**

DEVELOPMENT : the belief in the maintenance of two
 entirely distinct principles (such as matter
 and spirit)

DEVELOPMENT : the science of those
 features in organisms which refute the
 "design-argument"

EXTRINSIC : the outer (*ecto*) layer of the
 embryo

EXTRINSIC, the inner (*ecto*) layer of the
 embryo

EXTRINSIC : the outer layer of the skin

EXTRINSIC, the theory of gradual develop-
 ment of organs in the embryo

EXTRINSIC, the third or central eye in the
 early vertebrates

EXTRINSIC, see **SOMA**

EXTRINSIC : matter covering the surface of
 parts of the body (such as the mouth, etc.)

EXTRINSIC : the sexual glands

EXTRINSIC, separation of the male and
 female sexes

EXTRINSIC : sections of the sexual glands

EXTRINSIC : a male with the breasts
 (*male*) of a woman (*female*)

EXTRINSIC : pertaining to the liver (*hepato*)

EXTRINSIC, embryo in which the animal
 and vegetal cells divide equally (*divisio* or
 whole)

EXTRINSIC : the possession of more
 than the normal breasts (*male*)

EXTRINSIC : underneath (*hypo*) the
 gill-

EXTRINSIC : separation-offshoot from the
 brain in the primitive vertebrates

EXTRINSIC : see **SOMA**

LECITH-: pertaining to the yolk (*lecithin*); hence:—

Comelecithal: eggs with the yolk in the centre

Lecithoma: the yolk-sac

Telolecithal: eggs with the yolk at one end

MELOBLASTIC: cleaving in part (*meiosis*) only

MET-: (in compounds) the "after" or secondary stage, hence:—

Metagaster: the secondary or permanent gut (*gaster*)

Metoplasia: secondary or differentiated plasms

Metastoma: the secondary or permanent mouth (*stoma*)

Metasoma: the higher or later somata, made up of many cells

Metosoma: the mature or advanced soma

METAMER-: the segments into which the embryo breaks up

METAMERISM: the segmentation of the embryo

METEM-: the main portions of the metacellular organisms

Metem: built in the fundamental unity of all things

Metemphysis: the manner of organs, Kerm- (generally equivalent to anatomy)

MYOTOMA: segments into which the muscle breaks up

NEPHRA: the kidneys, hence:—

Nephridia: the rudimentary kidney-organs

Nephrotomes: the segments of the developing kidneys

ONTOGEN-: the course of the development of the individual (generally equivalent to embryology)

PARAKINESIS: the genesis of the movements in the vital particles

PHAGOCYTIC: cell-within-a-cell food (*phagocytosis* = to eat)

PHYLOGEN-: the science of the evolution of species (*physis*)

PLASMOTIC: cells that move about (*plasma*)

PLASM: the colloid or jelly-like matter of which organisms are composed, hence:—

Caryoplasm: the matter of the nucleus (*caryon*)

Cytoplasm: the matter of the body of the cell

Diatoplasm: secondary or differentiated plasms

Metoplasm: same as preceding

Protoplasm: primitive or undifferentiated plasms

PLASMA: the simplest form of plasms

PLASTIDIA: small particles of plasms

POLYMERISM: the penetration of more than one sperm-cell into the ovum

PRO- or **PROT-**: (in compounds) the earlier form (apposed to *MET-*); hence:—

Prochroma: the first form of the chromatin

Progonema: the first reproductive nucleus

Protoplast: the earlier form of the tubercle

Proovum: same as preceding

Prostoma: the first or primitive mouth

Protode: the earliest or unicellular organism

Protoplastem: the earliest phase of the protoderm

Protophyta: the primitive or unicellular plants

Protoplast: undifferentiated plasms

Protoplast: the primitive or unicellular animals

RHIZA: pertaining to the radicle (*rhiza*)

SEPARATION: picking or sorting up (*separare* = to sort)

SLEEP-STOMA: segmental slit which the primitive vertebrae take

SOMA: the body, hence:—

Cytoplasm: the body of the cell (*cytos*)

Epi-soma: the upper or back-half of the embryonic body

Stomion: segment of the embryonic body

Hypo-soma: the under or belly half of the embryonic body

TELIOLOGY: the belief in design and purpose (*telos*) in nature

TELIOLOGICAL: see *TELIOLOGY*

UTERINUM: pertaining to the nest (*uterus*)

UTELLUM: pertaining to the yolk (*utellus*)

PREFACE

[By JOSEPH MCCABE]

THE work which we now place within the reach of every reader of the English tongue is one of the finest productions of its distinguished author. The first edition appeared in 1874. At that time the conviction of man's natural evolution was even less advanced in Germany than in England, and the work raised a storm of controversy. Theologians—forgetting the commonest facts of our individual development—spoke with the most profound disdain of the theory that a Luther or a Goethe could be the outcome of development from a tiny speck of protoplasm. The work, one of the most distinguished of them said, was “a flock of shams on the ewe-sheep of Germany.” To-day its conclusion is accepted by influential clerics, such as the Dean of Westminster, and by almost every biologist and anthropologist of distinction in Europe. Evolution is not a laboriously reached conclusion, but a guiding truth, in biological literature to-day.

There was ample evidence to substantiate the conclusion even in the first edition of the book. But fresh facts have come to light in each decade, always enforcing the general truth of man's evolution, and at times making clearer the line of development. Professor Haeckel embodied these in successive editions of his work. In the fifth edition, of which this is a translation, reference will be found to the very latest facts bearing on the evolution of man, such as the discovery of the remarkable effect of mixing human blood with that of the anthropoid ape. Moreover, the ample series of illustrations has been considerably improved and enlarged; there is no scientific work published, at a price remotely approaching that of the present edition, with so abundant and excellent a supply of illustrations. When it was issued in Germany, a few years ago, a distinguished biologist wrote in the *Frankfurter Zeitung* that it would secure immortality for its author, the most notable critic of the idea of immortality. And the *Daily Telegraph* reviewer described the English version as a “hardworn edition of Haeckel's monumental work,” and “an issue worthy of the subject and the author.”

The influence of such a work, one of the most constructive that Haeckel has ever written, should extend to more than the few hundred readers who are able to purchase the expensive volumes of the original issue. Few pages in the story of science are more arresting and generally instructive than this great picture of “mankind in the making.” The horizon of the mind is healthily expanded as we follow the search-light of science down the vast avenues of past time, and gaze on the unthought forms that enter

into, or illustrate, the line of our ancestry. And if the imagination recoils from the strange and remote figures that we fit up by our search-light, and hesitates to accept them as ancestral forms, science draws aside another veil and reveals another picture to us. It shows us that each of us passed, in our embryonic development, through a series of forms hardly less uncouth and unfamiliar. Nay, it traces a parallel between the two series of forms. ■ shows us man beginning his existence, in the ovary of the female infant, as a minute and simple speck of jelly-like plasma. It shows us (from analogy) the fertilised ovum breaking into a cluster of cohering cells, and folding and curving, until the limb-less, head-less, long-tailed *foetus* looks like a worm-shaped body. It then points out how gill-slits and corresponding blood-vessels appear, as in a lowly fish, and the finlike extremities bud out and grow into limbs, and so on; until, after a very clear up-stage, the definite human form emerges from the series of transformations.

It is with this embryological evidence for our evolution that the present volume is concerned. There are illustrations in the work that will make the point clear at a glance. Possibly too clear; for the simplicity of the idea and the eagerness to apply it as every point has carried many, who borrow hastily from Haeckel, out of their scientific depth. Haeckel has never shared their errors, nor encouraged their superficiality. He insists from the outset that a complete parallel could not possibly be expected. Embryonic life itself is subject to evolution. Though there is a general and substantial law—as some of our English and American authorities admit—that the embryonic series of forms recalls the ancestral series of forms, the parallel is blurred throughout and often distorted. It is not the obvious resemblance of the embryos of different animals, and their general similarity to our extinct ancestors in this or that organ, on which we must rest our case. A careful study must be made of the various stages through which all embryos pass, and an effort made to prove their real identity and therefore genealogical relation.

This is a task of great subtlety and delicacy. Many scientists have worked at it together with Professor Haeckel—I need only name our own Professor Salfour and Professor Ray Lankester—and the scheme is fairly complete. But the general reader must not expect that even so clear a writer as Haeckel can describe these intricate processes without demanding his very careful attention. Most of the chapters in this present volume (and the second volume will be less difficult) are easily intelligible to all; but there are points in which the line of argument is necessarily subtle and complex. ■ the hope that more readers will be induced ■ master even these more difficult chapters, I will give an outline of the characteristic argument of the work. Haeckel's distinctive services in regard to man's evolution have been: (1) The construction of a complete ancestral tree, though, of course, some of the stages in it are purely conjectural, and not final; (2) The tracing of the remarkable reproduction of ancestral forms in

the embryonic development of the individual. Naturally, he has not worked alone in either department. The second volume of this work will embody the first of these two achievements; the present one is mainly concerned with the latter. It will be useful for the reader to have a synopsis of the argument and an explanation of some of the chief terms invented or employed by the author.

The main theme of the work is that, in the course of their embryonic development, all animals, including man, pass roughly and rapidly through a series of forms which represents the succession of their ancestors in the past. After a severe and extensive study of embryonic phenomena, Haeckel has drawn up a "law" (in the ordinary scientific sense) to this effect, and has called it "the biogenetic law," or the chief law relating to the evolution (*genesis*) of life (*ontogeny*). This law is widely and increasingly accepted by embryologists and zoologists. It is enough to quote a recent declaration of the great American zoologist, President D. Starr Jordan: "It is, of course, true that the life-history of the individual is an epitome of the life-history of the race"; while a distinguished German zoologist (Straßburg) has described it as being of the same use to the biologist as spectrum analysis is to the astronomer.

But the reproduction of ancestral forms in the course of the embryonic development is by no means always clear, or even always present. Many of the embryonic phases do not recall ancestral stages at all. They may have done so originally, but we must remember that the embryonic life itself has been subject to adaptive changes for millions of years. All this is clearly explained by Professor Haeckel. For the moment, I would impress on the reader the vital importance of fixing the distinction from the start. He must thoroughly familiarise himself with the meaning of five terms. *Biogeny* is the development of life in general (both in the individual and the species), or the science describing it. *Ontogeny* is the development (embryonic and post-embryonic) of the individual (*see*), or the science describing it. *Phylogeny* is the development of the race or stem (*phylon*), or the science describing it. Roughly, *embryology* may be taken to mean embryology, and *phylogeny* what we generally call evolution. Further, the embryonic phenomena sometimes reproduce ancestral forms, and they are then called *palæogenetic* (from *palæ* = again): sometimes they do not recall ancestral forms, but are later modifications due to adaptation, and they are then called *neogenetic* (from *neos* = new or foreign). These terms are now widely used, but the reader of Haeckel must understand them thoroughly.

The first five chapters are an easy account of the history of embryology and evolution. The sixth and seventh give an equally clear account of the sexual elements and the process of conception. But some of the succeeding chapters must deal with embryonic processes so unfamiliar, and pursue them through so wide a range of animals in a brief space,

that, in spite of the non-illustrations, they will offer difficulty to many a reader. As our aim is to secure, not a superficial acquiescence in conclusions, but a fair comprehension of the truths of science, we have retained these chapters. However, I will give a brief and clear outline of the argument, so that the reader with little leisure may realize their value.

When the animal ovum (egg-cell) has been fertilized, it divides and sub-divides until we have a cluster of cohering cells, externally not unlike a raspberry or mulberry. This is the *morula* (= mulberry) stage. The cluster becomes hollow, or filled with fluid in the centre, all the cells rising to the surface. This is the *blastula* (hollow ball) stage. One half of the cluster then bends or folds in upon the other, as one might do with a thin indiarubber ball, and we get a case-shaped body with hollow interior (the first stomach, or "primitive gut"), an open mouth (the first or "primitive mouth"), and a wall composed of two layers of cells (two "germinal layers"). This is the *gastrula* (stomach) stage, and the process of its formation is called *gastrulation*. A glance at the illustration on p. 62 will make this perfectly clear.

So much for the embryonic process in itself. The application to evolution has been a long and laborious task. Briefly, it was necessary to show that *all* the multicellular animals, passed through these three stages, so that our biogenetic law would enable us to recognize them as reminiscences of ancestral forms. This is the work of Chaps. VIII. and IX. The difficulty can be realized in this way: As we reach the higher animals the ovum has to take up a large quantity of yolk, on which it may feed in developing. Think of the bird's "egg." The effect of this was to flatten the germ (the *morula* and *blastula*) from the start, and so give, at first sight, a totally different complexion to what it has in the lower animals. When we pass the reptile and bird stage, the large yolk almost disappears (the germ now being supplied with blood by the mother), but the germ has been permanently altered in shape, and there are now a number of new embryonic processes (membranes, blood-vessel connections, etc.). Thus it was no light task to trace the identity of this process of *gastrulation* in all the animals. It has been done, however; and with this introduction the reader will be able to follow the proof. The conclusion is important. If all animals pass through the curious *gastrula* stage, it must be because they all had a common ancestor of that nature. To this conjectural ancestor (it lived before the period of fossilisation begins) Haeckel gives the name of the *Gastrea*, and in the second volume we shall see a number of living animals of this type ("gastrea-like").

The line of argument is the same in the next chapter. After laborious and careful research (though this stage is not generally admitted in the same sense as the previous one), a fourth common stage was discovered, and given the name of the *Cnidoblasta*. The *blastula* had one layer of cells, the *blastoderm* (*derma* = skin): the *gastrula* two layers, the *ectoderm* ("outer skin") and *endoderm* ("inner skin"). Now a third layer (*mesoderm*

a middle skin) is formed, by the growth inward of two pouches or folds of the skin. The pouches blend together, and form a single cavity (the body cavity, or *cœlom*), and its two walls are two fresh "germinal layers." Again, the identity of the process has to be proved in all the higher classes of animals, and when this is done we have another ancestral stage, the *Cnidostoma*.

The remaining task is to build up the complex frame of the higher animals—always showing the identity of the process (on which the evolutionary argument depends) in enormously different conditions of embryonic life—out of the four "germinal layers." Chap. IX. prepares us for the work by giving us a very clear account of the essential structure of the back-boned (vertebrate) animal, and the probable common ancestor of all the vertebrates (a small fish of the lamprey type). Chaps. XI.-XIV. then carry out the construction step by step. The work is now simpler, in the sense that we leave all the invertebrate animals out of account; but there are so many organs to be fashioned out of the four simple layers that the reader must proceed carefully. In the second volume each of these organs will be dealt with separately, and the parallel will be worked out between its embryonic and its phylogenetic (evolutionary) development. The general reader may wait for this for a full understanding. But in the meantime the wonderful story of the construction of all our organs in the course of a few weeks (the human frame is perfectly formed, though less than two inches in length, by the twelfth week) from so simple a material is full of interest. It would be useless to attempt to summarise the process. The four chapters are themselves but a summary of it, and the eighty fine illustrations of the process will make it sufficiently clear. The last chapter carries the story on to the point where man at last parts company with the anthropoid ape, and gives a full account of the membranes or wrappers that enfold him in the womb, and the connection with the mother.

In conclusion, I would urge the reader to consult, at his free library perhaps, the complete edition of this work, when he has read the present abbreviated edition. Much of the text has had to be condensed in order to bring out the work at our popular price, and the beautiful plates of the complete edition have had to be omitted. The reader will find it an immense assistance if he can consult the library edition.

JOSEPH McCALL.

Cambridge, March, 1906.

HAECKEL'S CLASSIFICATION OF THE ANIMAL WORLD

Unicellular animals (Protozoa)

1. Uninucleated {
 - Protozoa
 - Protozoa
2. Nucleated {
 - a. Rhizopoda {
 - Amoebium
 - Radiolarians
 - b. Infusoria {
 - Flagellata
 - Ciliata
3. Cell-colonies {
 - Caulobacteria
 - Microzoa

Multicellular animals (Metazoa)

I.
Cnidaria,
Cnidaria, or
Scaphyzoa.
Animals without
body-cavity, blood
or anus.

- a. Ctenophora {
 - Ctenophora
 - Ctenophora
- b. Sponges {
 - Spongia
 - Spongia
- c. Cnidaria (stinging animals) {
 - Hydrozoa
 - Scyphozoa
 - Anthozoa
- d. Plutei (flat-worms) {
 - Plutei
 - Plutei

II.
Cnidaria or
Bilateria.
Animals with body-
cavity and anus,
and generally
blood.

- a. Vertebrates (mammals) {
 - Vertebrates
 - Vertebrates
- b. Mollusca {
 - Mollusca
 - Mollusca
- c. Articulata {
 - Articulata
 - Articulata
- d. Echinodermata {
 - Echinodermata
 - Echinodermata
- e. Tunicata {
 - Tunicata
 - Tunicata
- f. Vertebrates {
 - Vertebrates
 - Vertebrates

* This classification is given for the purpose of explaining Haeckel's use of terms in this volume. The general reader should bear in mind that it differs very considerably from more recent schemes of classification. He should compare the scheme found by Professor E. Ray Lankester.

THE EVOLUTION OF MAN

CHAPTER I.

THE FUNDAMENTAL LAW OF ORGANIC EVOLUTION

ral phenomena into which I would introduce my readers in the following chapters, has a quite peculiar place in the broad realm of scientific inquiry. There is no object of investigation that touches ours more closely, and the knowledge of which should be more acceptable to him, than his own future. But among all the various branches of the natural history of mankind, or *anthropology*, the story of his development by natural means must surely be the most lively interest. It gives us the key of the great world-riddle at which the human mind has been working for thousands of years. The problem of the nature of man, or the question of man's place in nature, and the cognate inquiries as to the past, the present history, the present situation, and the future of humanity—all these come inseparable questions are directly and intimately connected with that branch of study which we call the science of the evolution of man, or, in one word, "anthropogeny" (the genesis of man). Yet it is an astonishing fact that the science of the evolution of man does not even yet form part of the scheme of general education. In fact, educated people even in our day are for the most part quite ignorant of the important truths and remarkable phenomena which anthropogeny teaches us.

As an illustration of this curious state of things, it may be pointed out that some of what are considered to be "educated" people do not know that every human being is developed from an egg, or ovum, and that this egg is one simple cell, like any other plant or animal egg. They are equally ignorant that in the course of the development of this tiny, round egg-cell there is first formed a body that is totally

different from the human frame, and has not the remotest resemblance to it. Most of them have never seen such a human embryo in the earlier period of its development, and do not know that it is quite indistinguishable from other animal embryos. At first the embryo is no more than a round cluster of cells, then it becomes a simple hollow sphere, the wall of which is composed of a layer of cells. Later it approaches very closely, at one period, to the anatomic structure of the lancelet, afterwards to that of a fish, and again to the typical build of the amphibian and mammal. As it continues to develop, a form appears which is like those we find at the latest stage of mammal-life (such as the duck-bill), then a form that resembles the marsupial, and only at a late stage a form that has a resemblance to the ape. And at last the definite human form emerges and closes the series of transformations. These suggestive facts are, as I said, still almost unknown to the general public—so completely unknown that, if one casually mentions them, they are called in question or denied outright as fairy-tales. Everybody knows that the butterfly emerges from the pupa, and the pupa from a quite different thing called a larva, and the larva from the butterfly's egg. But few besides radical men are aware that even, in the course of his individual formation, passes through a series of transformations which are not less surprising and wonderful than the familiar metamorphoses of the butterfly.

The mere description of these remarkable changes through which man passes during his embryonic life should arouse considerable interest. But the mind will experience a far deeper satisfaction when

we trace them various facts to their source, and when we have to remind us that several phenomena which are of the highest importance throughout the whole field of human knowledge. They throw light first of all on the "natural history of creation," then on psychology, or "the science of the mind," and through this on the whole of philosophy. And in the general results of every branch of inquiry are summed up in philosophy, all the sciences count in turn to be enriched and influenced more or less by the study of the evolution of man.

But when I say that I propose to present here the most important fragments of these phenomena and trace them to their source, I take the word, and I interpret my work, in a very much wider sense than is usual. The lectures which have been delivered on this subject at the universities during the last half-century are almost exclusively adapted to medical men. Certainly, the medical man has the greatest interest in studying the origin of the human body, with which he is daily concerned. But I must not give here this special description of the embryonic processes such as it has hitherto been given, in most of my readers have not studied anatomy, and are not likely to be concerned with the work of the adult organism. I must content myself with giving some parts of the subject only in general outline, and must not even upon all the questions, but very intricate and not easily described, details that are found in the story of the development of the human frame. To understand them fully a knowledge of anatomy is wanted. I will endeavor to do as far as possible in dealing with this branch of science. Indeed, a sufficient general idea of the nature of the embryonic development of man can be obtained without going too deeply into the anatomical details. I trust my way will be able to secure the more interest in this delicate field of inquiry, so far have pushed already in other branches of science; though we don't meet with anything here that elsewhere.

The story of the evolution of man, as it has hitherto been expounded to medical students, has usually been confined to embryology—more correctly, embryology—or the science of the development of the individual human organism. But this is really only the first part of our task, the first half of the story of the evolution of man in that wider sense in which we

understand it here. We must add to the second half—an another and not less important and interesting branch of the science of the evolution of the human race—physiology, this may be described as the science of the evolution of the human animal form, from which the human organism has been developed in the course of countless ages. Everybody now knows of the great scientific activity that was occasioned by the publication of Darwin's *Origin of Species* in 1859. The chief direct consequence of this publication was to produce a fierce inquiry into the origin of the human race, and this has proved beyond question far greater in extent than the other inquiry. We give the name of "Physiology" to this science which describes the growth of man from the top or roots of the united world. This short name that it draws upon for facts is "Embryology," or embryology, the science of the development of the individual organism. Moreover, it draws a great deal of support from paleontology, or the science of fossil remains, and even more from comparative anatomy, or morphology.

These two branches of our science—the one side anatomy, or embryology, and on the other physiology, or the science of the evolution of the individual organism. The one science is understood without the other. It is well known that the two branches fully cooperate and supplement each other that "Embryology" for the science of the structure of life in the widest sense; anatomy is the work of a physiological science. The connection between them is not external and superficial, but profound, intimate, and causal. This is a discovery made by recent research, and it is now clearly and correctly expressed in the comprehensive law which I have called "the fundamental law of organic evolution," or "the fundamental law of biology." This general law, to which all that comprises modern biology, and on the reputation of which depends man's whole right and the story of evolution, may be briefly expressed in the phrase "The history of the future is a recapitulation of the history of the past," or, in other words, "Ontogeny is a recapitulation of phylogeny." It may be more fully stated as follows: The series of forms through which the individual organism passes during its development from the zygote to the complete fully formed organism is a brief, condensed repetition

of the long series of forms which the natural members of the said organism, or the ancestral forms of the species, have passed through from the earliest period of organic life down to the present day.

The causal character of the relation which connects embryology with stem-history is due to the nature of heredity and adaptation. When we have rightly understood these, and recognized their great importance in the formation of organisms, we can go a way farther and say: 'Feytagement is the stem-historical cause of ontogenesis.' In other words, the development of the stem, or race, is, in accordance with the laws of heredity and adaptation, the cause of all the changes which appear in a descendant form in the evolution of the latter.

The chain of manifold animal forms which represent the ancestry of each higher organism, or race of man, according to the theory of descent, always forms a connected whole. We may designate this uninterrupted series of forms with the letters of the alphabet A, B, C, D, E, etc., to Z. In apparent contradiction to what I have said, the story of the development of the individual — the ontogeny of most organisms, only refers to the character a part of these forms, so that the definite series of embryonic forms would run A, B, D, F, H, K, M, etc., or, in other cases, B, D, H, L, N, P, etc. Now, then, as a rule, instead of the embryonic forms of the original series have fallen out. Moreover, we often find — in connection with our illustration from the alphabet — one or more of the original letters of the unbranched series represented by corresponding letters from a different alphabet. Thus, viewing of the Roman B and D, we often have the Greek B and D. In this case the loss of the digamma has been a-verted, just as it had been otherwise in the preceding case. But, in spite of all this, the story of ancestral forms remains the same, and we are in a position to discover our original embryonism.

In reality, there is always a certain parallel between the two evolutionary series. But it is obscured from the fact

that in the embryonic succession much is wanting that certainly existed in the earlier ancestral succession. If the parallel of the two series were complete, and if this great fundamental law affecting the causal connection between ontogeny and phylogeny in the proper sense of the word were directly demonstrable, we should only have to determine, by means of the microscope and the measuring beam, the series of forms through which the first-hand stem passes in its development; we should then have before us a complete picture of the remarkable series of forms which our animal ancestors have successively assumed from the dawn of organic life down to the appearance of man. But such a representation of the ancestral history by the individual is to everyone else in very rarely complete. We do not often find but a-lythion. In most cases the correspondence is very imperfect, many greatly obscured and hidden by causes which we will consider later. We are thus for the most part, unable to determine in detail, from the study of the embryology, all the different stages which an organism's ancestors have assumed; we usually and especially in the case of the human fetus — many gaps. It is true that we can fill up most of these gaps satisfactorily with the help of comparative anatomy, but we cannot do so from direct embryological observations. Hence it is important that we find a large number of lower animal forms to be still represented in the course of man's embryonic development. In these cases we may draw our conclusions with the utmost security as to the nature of the ancestral form from the features of the form which the embryo immediately assumes.

To give a few examples, we can infer from the fact that the first member of our series was a two-cellular being, something like the ascidian. In the same way, we learn, from the fact that the human fetus consists, at the first, of two simple cell-layers (the gastrula, that the gastrula, a form with two main layers, was primary in the line of our ancestry. A lower human embryonic form (the chordate) points just as clearly to a more-early ancestor (the protobranch), the common being neither of which is found among the actual members. To this must be added important embryonic stages (common to, in which our human being

* The law "proven" which every descendant form must follow in its development is the law of the "stem-history" of the species — the origin of the "ancestral" history in the sense of the word "ancestral" — the origin of the species (stem), and so on. It is not the law which governs the development of the individual, but the law which governs the development of the species.

process, in the origin, the structure of the tissues. But we can only indirectly and appreciatively, with the aid of comparative anatomy and histology, conjecture what is the true sequence and the chain of our ancestry between the germ and the chorion, and between the and the human. In the course of the historical development many intermediate structures have gradually fallen out, which now certainly have been represented in our ancestry. But, in spite of these aids, and sometimes very appreciable gaps, there is an insurmountable barrier between the two positions. In fact, it is the chief purpose of this work to prove the real history and the original position of the two. I begin in them on a historical basis of facts, that we can draw some important conclusions as to our general history from the actual and easily demonstrable series of embryonic changes. We shall then be in a position to form a general idea of the results of actual development have figured in the short line of our ancestry in the history history of organic life.

In this evolutionary approach of the facts of embryology we must, of course, take particular care to distinguish sharply and clearly between the primitive, pathogenic (or ancestral) evolutionary processes and those due to convergency. By pathogenic processes, or embryonic recapitulations, is understood all those phenomena in the development of the individual which are transmitted from one generation to another by heredity, and which, on that account, afford an excellent foundation as to recapitulating structures in the development of the species. On the other hand, we give the name of convergency processes, or embryonic variations, to all those phenomena in the fetal development that cannot be traced to inheritance from earlier species, but are due to the adaptation of the fetus, or the individual, to certain conditions of its embryonic development. These convergency phenomena are foreign to later addition; they allow us to draw no direct inference whatever as to recapitulating processes in the ancestral

history, but rather hinder us from doing so.

This careful discrimination between the primary or pathogenic processes and the secondary or convergency is of great importance for the purposes of the scientific history of a species, which has to draw conclusions from the available facts of embryology, comparative anatomy, and paleontology, as to the processes in the formation of the species in the remote past. It is of the same importance to the student of evolution as the careful distinction between genuine and spurious facts in the works of an ancient writer, or the sifting of the real text from interpolations and additions, is for the student of philology. It is true that this distinction has not yet been fully appreciated by many students. For my part, I regard it as the first condition for forming any just idea of the evolutionary process, and I believe that we must, in accordance with it, divide embryology into two sections—pathogenic, or the science of recapitulating forms, and convergency, or the science of superimposed structures.

To give a few examples from the science of man's origin as illustrations of this important distinction, I may mention the following processes in the embryology of man, and of all the higher vertebrates, as pathogenic, the formation of the two primary germinal layers and of the primitive gut, the withdrawal and closure of the dorsal notochord, the appearance of a single axial rod between the notochord tube and the gut, the temporary formation of the pre-somite and other, the posterior's bodies, and so on. All these, and many other important structures, have clearly been transmitted by a steady heredity from the early members of the mammal, and are, therefore, direct indications of the process of slower structures in the history of the species. On the other hand, there is certainly not the same with the future and embryonic forms which we now describe as convergency processes; the formation of the pubic bone, the alveolar, the placenta, the umbilical, the umbilical, and the chorion—or generally speaking, the various fetal membranes and the interdependent changes in the fetal fluids. Further examples are: the dual structure of the heart cavity, the temporary division of the plates of the primitive notochord, and

1 Pathogenic are both or representative, such as organs, processes or forms, developmental, which are transmitted to the structure which are represented by heredity from earlier members of the species. Convergency are foreign or superimposed development (forms and processes), which are phenomena which stand later in the history of life in which the original structure by a final adaptation is transformed. —Haeckel.

2 On the other hand, the convergency processes, which are superimposed on the pathogenic, are not to be regarded as such.

higher planes, the secondary starting of the central and lateral walls, the formation of the nerve, and so on. All these and many other phenomena are certainly not impossible to similarly structures in any earlier and completely developed ancestral form, but have arisen simply by adaptation to the peculiar conditions of embryonic life (within the fetal membrane). In spite of these facts, we may now give the following more precise description to the chief law of biology. The existence of the fetus (or embryo) is a conditioned and determined manipulation of the evolution of the germ (or phylogenesis); and this manipulation is also more complete or superficial on the original development of phylogenesis is preserved by a constant heredity; on the other hand, it becomes less complete in proportion to a varying adaptation to new evolutionary conditions. The modifying factors in the development (for *ontogeny* term).

The consequent alterations or distortions of the original phylogenetic course of development like the form, as a rule, of a gradual displacement of the phenomena, which is chiefly effected by adaptation to the changed conditions of embryonic existence during the course of thousands of years. This displacement may take place in regular either the position or the form of a phenomenon.

The great importance and deep significance of the latter criterion in embryology have been carefully worked out by Ernst Haeckel, in his *Monism in the Philosophy of Science*. He contends that our knowledge here has not been impaired by the attacks of its opponents, and goes on to say: "Naturally any party of biologists has contributed no much to the advance of embryology as this, the knowledge as one of the most rapid sources to general biology. It was not until the late period into the flesh and blood of neo-physiology, and they had examined themselves to see a reconstruction of general biology in embryonic structure, that we witnessed the great progress which embryology has made within the last two decades." The best proof of the correctness of this opinion is that now the most fruitful work is done in all branches of embryology with the aid of this biological law, and that it enables students to obtain every year thousands of brilliant results that they would never have reached without it.

It is only to have any appreciation the significance of this law in relation to the

phylogenetic, and when one takes careful account of the changes which the latter may suffer from the former, that the real importance of the biological law is recognized, and it is fit to be the main dominating principle in the science of evolution. Is the task of discerning it in the other things in relation to which we can arrange all the phenomena of this realm of nature the "Artistic thread," which runs through us to find our way through the labyrinth of forms. Hence the greatest benefit, the advantage, could say with perfect justice to their study of the problems of the *Archetype*, that "the great importance here is just as important for the biologist as having important problems as a general analysis is for the astronomer."

Even at an earlier period, when a correct acquaintance with the structure of the human and animal brain was only just being obtained and that is scarcely thirty years ago, the greatest scientific work was left to the embryology, which is observed between the embryonic forms, or stages of development, in very different animals, attention was called to us that to these close resemblance to common facts observed among forms belonging to some of the lower groups. The same conditions (form, structure, and others) were perfectly well that little lower forms in a more distorted and fixed, in the history of the animal world, a secondary stage in the evolution of higher forms. The famous anatomist Meckel, quoted in the of a secondary between the development of the embryo and the course of ontogeny. "Now comes the question—shall we have to solve the problem? Yes, the embryonic form of the higher animals among the permanent stages of evolution of lower groups. But it is impossible to understand and appreciate the remarkable resemblance of that case. We use our capacity to do this in the theory of descent. It is this that gave to their true light the nature of heredity on the one hand and adaptation to the other. It explains to us the real importance of their constant reappearance in the production of organic forms. There is one the best to teach us the great part that was played in this by the numerous struggle for existence between living things, and to show how, under the influence of this for natural selection, new species were produced and maintained, solely by the inheritance of heredity and

other mammals, at the same stage of embryony. We had a lance-shaped body of very simple construction, with a tail-like end and a pair of fins at the sides, something like those of a fish, but very different from the bodies of man and the monkey. Nearly the whole front half of the body is taken up by a chamber-head without fin, in the sides of which we find gill-slits and arches as in the fish. At the stage of development the human embryo does not differ in any essential detail from that of the ape, dog, horse, cat, etc. at a corresponding period. This important fact can only be verified at any moment by a comparison of the embryos of man, the dog, rabbit, etc. Moreover, the physiologist and medical philosopher pronounced it to be a fundamental law: even anatomy, to which the facts should be known, have taught us this lesson.

There could not be a deeper proof of the profound similarity of these embryological facts in favour of the Darwinian philosophy than is afforded by the efforts of the opponents to get rid of them by claims of accident. The truth is that these facts are most incontrovertible for them, and are quite irreconcilable with their view. We must be all the more pressing on our side to put them in their proper light. I fully agree with Huxley when he says, in his *Athenæum* of Nature: "Though these facts are covered by words and become popular leaders they are easy to prove, and are sustained by all reliable facts, on the other hand, their acceptance is so great that those who have once accepted them will, in my opinion, find few other biological doctrines so acceptable to them."

We shall enter in our third book to study the evolution of man's body from all the various organs in their external form and internal structure. But I may observe at once that this is accomplished step by step with a study of the evolution of these functions. These two branches of inquiry are inseparably united in the whole of our biology, just as in zoology (of which the former is only a section) or general biology. Everywhere the parallel form of the organism and its structure, internal and external, is directly related to the special physiological functions which the organism or organ has to execute. This intimate connection of structure and function, or of the instrument and the work done by it, is seen in the

course of evolution and all its parts. Hence the study of the evolution of structure, which in our immediate concern is also the history of the development of functions; and this holds good of the human organism as of any other.

At the same time, I must admit that our knowledge of the position of functions is very far from being as complete as our acquaintance with the evolution of structure. One might say, in fact, that this whole science of position has almost confined itself to the study of structure; the evolution of functions hardly came into being. That is the fault of the physiologists, who have as yet remained themselves very little about evolution. It is only in recent times that physiologists like W. Engelmann, W. Preyer, H. Vervaeke, and a few others, have entered the domain of functions.

It will be the task of some future physiologist to engage in the study of the evolution of functions with the same zeal and vision as has been done for the evolution of structure in morphology. The origin of the genesis of heart. Let me observe the close connection of the two by a couple of examples. The heart in the human embryo has at first a very simple construction, such as we find in primitive forms among the earthworm and other annelids, and this is described in a very simple system of circulation of the blood. Now when we find that with the development heart there comes a really different and much more intricate circulation, we require then the development of the heart to explain all over not only an evolution, but also a physiological study. Thus it is clear that the anatomy of the heart can only be understood on the light of the physiology (or, at least, in the part), both as regards function and structure. The same holds true of all the other organs and their functions. For instance, the course of the evolution of the stomach cannot be traced, or the origin, origin, going on at the same time, through the exact comparative investigation of structure and function, most important information with regard to the evolution of the functions of these organs.

This significant connection is very clearly seen in the evolution of the nervous system. The system is in the course of the human body the nucleus of sensation, will, and even thought, the highest of the psychic functions; in a word, of

fact is that these embryological phenomena themselves demand explanation in turn, and this can only be found, as a rule, in the corresponding changes in the

long ancestral series, or in the physiological functions of heredity and adaptation.

CHAPTER II.

THE OLDER EMBRYOLOGY

It is in many ways useful, on entering upon the study of any science, to cast a glance at its historical development. The saying that "everything is best understood in its growth" has a distinct application to science. While we follow its gradual development we get a clearer insight into its aims and objects. Moreover, as we shall see that the present condition of the science of human evolution, such as its characteristics, can only be rightly understood when we examine its historical growth. This task will, however, not detain us long. The study of man's evolution is one of the latest hypotheses of natural science, a further step towards the embryological or the phylogenetic section of it.

Apart from the few germs of our science which we find in classical antiquity, and which we shall notice presently, we may say that it takes its definite form, as a science, at the year 1759, when one of the greatest German scientists, Caspar Friedrich Wolff, published his *Thesaurus generationis*. That was the foundation-stone of the science of animal embryology. It was not until fifty years later, in 1810, that Jean Lamarck published his *Philosophie Zoologique*—the first effort to provide a base for the theory of evolution; and it was another half-century before Darwin's work appeared (in 1859), which we may regard as the first scientific attainment of this aim. But before we go further into this solid establishment of evolution, we must cast a brief glance at that famous philosopher and scientist of antiquity, who stood alone in this, as in many other branches of science, for more than 2,000 years: the "father of natural history," Aristotle.

The extent scientific works of Aristotle deal with many different sides of biological research, the most comprehensive of them is his famous *History of Animals*. But not less interesting is the smaller work, *On the Generation of Animals* (*Peri geneseos*). This work treats especially of embryonic development, and it is of great interest as being the earliest of its kind and the only one that has come down to us in any completeness from classical antiquity.

Aristotle studied embryological questions in various classes of animals, and among the lower groups he learned many most remarkable facts which we only rediscovered between 1830 and 1850. It is certain, for instance, that he was acquainted with the very peculiar mode of propagation of the cuttle-fishes, or cephalopods, in which a yelk-sac hangs out of the mouth of the fetus. He knew, also, that embryos came from the eggs of the bee even when they have not been fertilised. The "parthenogenesis" (or virgin-birth) of the bee has only been established in our time by the distinguished zoologist of Munich, Seebach. He discovered that male bees come from the unfertilised, and female bees only from the fertilised, eggs. Aristotle further states that some kinds of fishes (of the genus *serpens*) are hermaphrodites, each individual having both male and female organs and being able to fertilise itself; this, also, has been recently confirmed. He knew that the embryo of many fishes of the shark family is attached to the mother's body by a sort of placenta, or nutritive organ very rich in blood; apart from these, such an arrangement is only found among the higher mammals and

egg. This phantasm of the shark was hatched upon its legendary life a long time, until Johannes Müller proved it to be a fish in disguise. Thus a number of remarkable discoveries were found in Aristotle's embryological work, proving a very good acquaintance of the great mind—with possibly by his predecessors—with the facts of anatomy, and a great advance upon wandering generalizations in this respect.

In the case of many of these discoveries he did not merely describe the facts, but added a number of observations on a systematic basis of these observations, especially one of particular interest, namely that there is a constant appreciation of the nature of the embryonic processes. He speaks of the development of the individual as a new formation, in the course of which the various parts of the body take their systematic place. Thus the human or animal form is developed in the mother's body, or separately in an egg, the heart—which he regards as the starting-point and centre of the organism—must appear first. Over the heart is formed the outer organs, then the internal ones before the external, the lungs (there above the diaphragm) before the liver (or below beneath the diaphragm). The brain is formed at an early stage, and the eyes grow out of it. These observations are quite correct. And, if we try to learn something about these data of Aristotle's general conception of the embryonic process, we find a close proximity of the theory which Wolff showed a few years afterwards to be the correct view. It is significant, for instance, that Aristotle denied the identity of the individual in any respect. He said that the species or genus, the group of similar individuals, might be eternal, but the individual was transitory. It rather was to beg in the act of procreation, and pass away in death.

During the same years after Aristotle the progress whatever was made in general biology, or in embryology in particular. People were content to read, copy, translate, and comment on Aristotle. Scarcely a single independent effort at research was made in the whole of the period. During the Middle Ages the superstitious religious beliefs put Aristotelian statements in the way of independent scientific investigation. There was no question of running the advance of biology. Even when human anatomy began to stir itself

independent research was confined into the vicarious of the developed body. Anatomists did not dare to extend their inquiries to the unfurled body, the embryo, and its development. There were many reasons for the prevailing horror of such matters. It is natural enough, when we remember that a Paul of Bordeaux VIII, excommunicated every man who ventured to dissect a human corpse. If the dissection of a developed body were a crime to be thus punished, how much more dreadful crime it have seemed to deal with the embryonic body still enclosed in the womb, which the Creator himself had decreed to be hidden from the curiosity of the student! The Christian Church, therefore, gave many thousands to death for venturing, and a shroud of yew-wood of the cemetery that science maintained against its authority. It was not until enough to see that the soul did not grow so quickly.

It was not until the Renaissance broke the power of the Church, and a new world of the spirit showed the way, when that human nature, that humanity and embryology, and other other branches of research, could begin to advance more easily. However, embryology lagged far behind anatomy. The first work on embryology appeared at the beginning of the sixteenth century. The Italian anatomist, Fabrizio ab Acquapendente, a physician at Padua, opened the subject for his two books (*De formatione foetus*, and *De formatione foetus*, 1564) by publishing the oldest observations and descriptions of the embryo of man and other mammals, and of the form. Notable important illustrations were given by Sigheum (*De formatione foetus*, 1561), and by Bonduinus (1565) and by more human comparisons. Harvey (1651) who described the circulation of the blood in the animal body and formulated the important principle, that every animal is born (all the organs have got something like). The Italian physician, Bernardino Rudbeck in his *Abile of Nature* (the earliest observations on the embryology of the frog and the chicken of an egg-shell. But the most important embryological system in the sixteenth century were those of the famous Italian, Marcello Malpighi, of Bologna, who laid the way both in biology and anatomy. His treatise, *De formatione foetus* and *De ore animalis* (1671), contains the first complete description of the development of the chick in the fertilized

There I ought to say a word about the important part played by the chick in the growth of our science. The development of the chick, like that of the young of all other birds, agrees in all its main features with that of the other chief vertebrates, and even of man. The three highest classes of vertebrates—mammals, birds, and reptiles (lizards, serpents, tortoises, etc.) have from the beginning of their evolutionary development as striking a resemblance to all the chief groups of crustacea, and especially to their first forms, that for a long time it is impossible to distinguish between them. We have known ever for some time that we need only examine the embryo of a bird, which is the easiest to get at, in order to learn the typical mode of development of a mammal (and therefore of man). As soon as scientists began to study the human embryo, or the mammalian embryo generally, in an earlier stage than the middle and end of the nineteenth century, this importance became very quickly recognized. It is both theoretically and practically of great value. As regards the theory of evolution, we can draw the most weighty inferences from the similarity between the embryos of widely different classes of animals. But for the practical purposes of embryological research the discovery is invaluable, because we can fill up the gaps in our imperfect knowledge of the embryology of the remainder from the more thoroughly studied embryology of the bird. How? eggs are much to be had in any quantity, and the development of the chick may be followed step by step in artificial incubators. The development of the mammal is much more difficult to follow, because here the embryo is not detached and enclosed in a large egg, but the tiny ovum remains in the womb until the growth is completed. Hence, it is very difficult to keep up sustained observation of the various stages in any given species, quite apart from such relative considerations as the cost, the technical difficulties, and many other obstacles which we encounter when we would make an intensive study of the fourth mammal. The chicken has, therefore, always been the chief object of study in this connection. The excellent literature we now have enables us to observe it in any quantity and at any stage of development, and to follow the whole course of the formation step by step.

By the end of the nineteenth century histology had advanced as far as it was possible to do with the imperfect microscope of his time in the embryological study of the chick. Further progress was prevented until the instrument and the technical methods should be improved. The vertebrate embryos are so small and delicate in their earliest stages that you cannot go very far into the study of them without a good microscope and other valuable aid. But this technical improvement of the microscope and the other apparatus did not take place until the beginning of the twentieth century.

Embryology made steady advance in the first half of the nineteenth century, when the systematic natural history of plants and animals received its greatest impulse through the publication of *Levy's General System of Nature*. But until 1890 did the genius arise who was to give it an entirely new character, August Weismann. Until then embryology had been accepted almost exclusively as confirmation and misleading efforts to build up theories on the important empirical material then available.

The change which then prevailed, and continued to grow throughout nearly the whole of the nineteenth century was commonly called at that time "the evolution theory." It is better to describe it as "the phylogenetic theory." Its chief point is this: There is no pre-formation of structures in the embryonic development of any organism, animal or plant, or even of man. There is such a growth, or unfolding, of parts which have been constructed or pre-formed from all particles, though on a very small scale and closely packed together. Hence, every living germ contains all the organs and parts of the body, in the form and arrangement they will present later, already within it, and therefore the whole embryological process is merely an unfolding in the final sense of the word, or an unfolding of parts that were pre-formed and folded up in it. So, for instance, we find in the hen's egg not merely a single cell that divides and subdivides and forms germinal layers, and at last, after all kinds of variation and time and generations, brings forth

* The theory is usually known as the "evolution theory," or "phylogenetic theory." It is in the sense that it is the "evolution theory" of the organism, as opposed to the "ontogenetic theory" of the individual. It is the theory of the development of the species, as opposed to the development of the individual.

the body of the child; but there is in every egg from the first a complete embryo, with all its parts made and nearly perfect. These parts are so small or so imperfect that the microscope cannot detect them. In the hatching, these parts merely grow larger, and spread out in the normal way.

When this theory is consistently developed it becomes a "creationism theory." According to it, hatching, there was made in the beginning one couple or one individual of each species of animal or plant; but this one individual contained the germs of all the other individuals of the same species who should ever come to life. At the age of the earth it is generally believed at this time to be fixed by the Bible at 6,000 or 6,001 years, it would be possible to calculate how many individuals of each species had lived in the period, and to find how packed inside the first being that was created. The theory is consistently extended to man, and it is asserted that our common ancestor Eve had stood at her work the germs of all the children of men.

The theory at first took the form of a belief that it was the Father who was there seated in the first being. One couple of each species was created, but the female extended at her work till the future individuals of the species, of future men. However, she had to be able to live the Dutch microscope. Lenses were, however, the male spermatozoa in eggs, and showed that an enormous number of them swarmed like flies and made thread-like long rows in the male spermatozoa all by captured in the female (chapter). This amazing discovery was further advanced when it was proved that these long bodies, swimming about in the animal fluid, were real individual cells. In fact, were the preformed germs of the future generation. When the male and female progressed separately came together at conception, these thread-like spermatozoa ("seed-sperms") were supposed to penetrate into the female body of the ovum and begin to develop there, as the plant seed does in the fertilized earth flower, every spermatozoon was regarded as a human stem, a tiny complete man. All this part was believed to be pre-formed in it, and surely grew larger as it continued its proper motion in the female

ovum. This theory, then, was immediately developed in the view that in each of them (human eggs) before the whole of its personality was supposed to be present in the maternal form. Adam's original germ was thought to have contained the germs of the whole of humanity.

The "theory of male creation" found itself at once to have application to the prevailing "female" theory. The two rival theories at once opened a very lively campaign, and the physiologists of the eighteenth century were divided into two great camps—the transcendents and the Chonders, which fought vigorously. The transcendents held that the spermatozoa were the true germs, and applied to this theory microscopes and the writings of these fathers. The opposing party of the Chonders, who clung to the older "evolution theory," asserted that the eggs in the end germ, and that the spermatozoa merely stimulated it at conception to begin its growth, all the future generations are stored in the ovum. This view was held by the great majority of the biologists of the eighteenth century, in spite of the fact that Waller proved it in 1790 to be a wrong view. It was only a passage directly to the evolutionism that the most sagacious biologists of the century, and philosophers of the day decided in favor of it, especially Huxley, Darwin, and Lyell.

After the failure, perhaps as God thought, was to often called the failure of the village, was a sort of wide and varied knowledge, but he did not carry a very high position at present to create the natural philosopher. He was a "great discoverer" of the "evolution theory" in his famous work, *Aboriginal Philosophy*, following "Three or four things in human nature are explained." The part of the animal body is made in two another, all are made together. He then decided that there was any evolution in the proper sense of the word, and even went so far as to say that the human mind in the human form, all the parts were there in advance, and were merely hidden from the eye of man for the teaching. Huxley even calculated the number of human beings that God would have created on the sixth day and showed it as in his own way. He put the number of men, one million, assuming that age of the world to be four years, the average age of a human being to be thirty years, and the population of the world at

* "Father's story" said in the last translation. *Aboriginal Philosophy* is a book by Huxley.

just then to be 3,000 million. And the famous Mäller maintained all this nonsense, in spite of his scientific scrupulousness, even after Wall's had discovered the real causes of embryonic development and established it by direct observation.

Among the philosophers of the time the distinguished Lamarck was the chief defender of the "preformation theory," and by his authority and literary prestige many others were led to be supported by his system of scientific reasoning to which he and most men turned in completely unexamined and by those united with the popular belief of the "instinct," "Lamarckianism" extended the "evolution theory" to the mind, and held that this was no more evolved than the body. He says, for instance, in his *Philosophie*: "I mean that these organs, which one day are to be the work of man, are present in the seed, like those of other species; in such way that they existed in our ancestors in the same manner as from the beginning of the world, in the form of organized matter."

The theory seemed to render evolution after nature itself, the development of man in the same manner as organisms. It was in 1846 he discovered, in the plant-brood, a case of parthenogenesis, or virgin-birth, an interesting form of reproduction that has lately been found by Seward and others among various classes of the animal kingdom, especially crustaceans and insects. Among those who were advocates of certain hypotheses the brood now reproduced by asexual generation without having been fertilized by the male. These are that the sea urchin fertilization are called "false eggs," vermin or spores. Seward said that a female plant-brood, which he had kept in closed isolation, and rigidly separated from contact with males, had on the seventh day (after forming a new skin for the fourth time) a living daughter, and during the next twenty days twenty-five other daughters, and that all of them went on to reproduce in the same way without any contact with males. It seemed as if this furnished an irrefragable proof of the truth of the preformation theory, as it was held by the thinkers; it is not surprising to find that the theory then received general acceptance.

That was the condition of things when suddenly, in 1858, August Weismann's Wall appeared, and took a long blow at the whole preformation theory with his new theory of evolution. What was one of a

Wall's father, was born in 1823, and went through his scientific and medical studies, first at Berlin under the famous anatomist Meckel, and afterwards at Halle. Here he entered the discussion in his twenty-sixth year, and in his numerous dissertations (Marburg 1850, 1851, the *Theoria generativa*, expanded the old theory of a seed development on a basis of epigenesis. This position is, in spite of his mistakes and his obscure philosophy, one of the most valuable in the whole range of biological literature. It is especially distinguished for the mass of new and careful observations it contains, and the far-reaching and pregnant ideas which the author everywhere carries into his descriptions and builds into a luminous and concise theory of generation. Nevertheless, it met with no success at the time. Although scientific studies were then everywhere reaching and owing to the impulse given by Linné-alike biologists and zoologists were no longer cramped by dogma, but by habit, hardly any notice was taken of Wall's theory. It is when

he established the truth of epigenesis by the most rigorous observations, and demolished the very structure of the preformation theory the same "instinct" Mäller proved one of the most ardent supporters of the old theory and against Wall's correct view with a determined "There is no such thing as evolution." He even went so far as to say that epigenesis was contained by the old theory! It is not surprising that the whole of the philosophy of the second half of the eighteenth century continued to the young of this still-developed period, and attacked the theory of epigenesis as a dangerous innovation. It was not until more than fifty years afterwards that Wall's work was appreciated. Only when his old friend Richard von Germar in other another valuable work of Wall's on *The Formation of the Jurastrasse Canal* (written in 1856), and called attention to its great importance, did people begin to think of him once more; yet this obscure writer had earned a preponderant weight into the nature of the living organism than any other scientist of the eighteenth century.

Wall's idea led to an appreciable advance over the whole field of biology. There is such a vast number of new and important observations and pregnant thoughts in his writings that we have only gradually begun to appreciate their value to the science of the nineteenth

century. He opened up the firm path for research in many directions. In the first place, his theory of epigenesis gave us the first real insight into the nature of embryonic development. He showed convincingly that the development of every organism consists of a series of *new formations*, and that there is no trace whatever of the complete form either in the ovum or the spermatozoon. On the contrary, these are quite simple bodies, with a very different purport. The embryo which is developed from them is also quite different, in its internal arrangement and outer configuration, from the complete organism. There is no trace whatever of preformation or in-folding of organs. To-day we can accurately call epigenesis a *theory*, because we are convinced it is a fact, and one demonstrable at all any moment with the aid of the microscope.

Wolff furnished the conclusive empirical proof of his theory in his classic description on *The Formation of the Alimentary Canal* (1766). In its complete state the alimentary canal of the hen is a long and complex tube, with which the lungs, liver, salivary glands, and many other small glands, are connected. Wolff showed that in the early stages of the embryonic chick there is no trace whatever of this complicated tube with all its dependencies, but instead of it only a flat, leaf-shaped body; that, in fact, the whole embryo has at first the appearance of a flat, oval-shaped leaf. When we remember how difficult the exact observation of so fine and delicate a structure as the early leaf-shaped body of the chick must have been with the poor microscopes then in use, we must admire the

Wolff so makes the most important discoveries in this most difficult part of embryology. By his laborious research he corrects opinions that the embryonic body of all the higher animals, such as the birds, is for some time merely

a flat, thin, leaf-shaped disk—consisting at first of one layer, but afterwards of several. The lowest of these layers is the gut cavity, and Wolff followed its development from its commencement to its completion. He showed how this leaf-shaped structure first turns into a groove, then the margins of this groove fold together and form a closed canal, and at length the two external openings of the tube (the mouth and anus) appear.

Moreover, the important fact that the other systems of organs are developed in the same way, from tubes formed out of simple layers, did not escape Wolff. The nervous system, muscular system, and vascular (blood-vessel) system, with all the organs appertaining thereto, now, like the alimentary system, developed out of simple leaf-shaped structures. Hence, Wolff came to the view by 1768 which Pander developed in the *Theory of Germinal Layers* fifty years afterwards. His principles are not literally correct; but he comes as near to the truth in them as was possible at that time, and could be expected of him.

Our admiration of this gifted genius increases when we find that he was also the precursor of Goethe in regard to the outer-morphology of plants and of the famous cellular theory. Wolff had, as Haeckel showed, a clear presentiment of this cardinal theory, since he recognized small microscopic niches as the elementary parts out of which the germinal layers arose.

Finally, I must invite special attention to the emphatic character of the profound philosophic reflections which Wolff always added in his remarkable observations. He was a great monistic philosopher, in the best meaning of the word. It is unfortunate that his philosophic discoveries were ignored as completely as his observations for more than half a century. We must be careful to comprehend the fact of this clear monistic tendency.

CHAPTER III.

MODERN EMBRYOLOGY

We may distinguish three chief periods in the growth of our science of human embryology. The first has been considered in the preceding chapter. It embraces the whole of the preparatory period of research, and extends from Aristotle to Caspar Friedrich Wolff, or to the year 1739, in which the epoch-making *Theoria generationis* was published. The second period, with which we have now to deal, lasts about a century—that is to say, until the appearance of Darwin's *Origin of Species*, which brought about a change in the very foundations of biology, and, in particular, of embryology. The third period begins with Darwin. When we say that the second period lasted a full century, we must remember that Wolff's work had remained almost unnoticed during half the time—namely, until the year 1812. During the whole of those fifty-three years not a single book that appeared followed up the path that Wolff had opened, or extended his theory of embryonic development. We merely find his views—perfectly correct views, based on extensive observations of fact—mentioned here and there as erroneous; their opponents, who adhered to the dominant theory of preformation, did not even deign to reply to them. This unjust treatment was chiefly due to the extraordinary authority of Albrecht von Haller: it is one of the most astonishing instances of a great authority, on such a promising line for a long time the recognition of established facts.

The general ignorance of Wolff's work was so great that at the beginning of the nineteenth century two scientists of Jean, Oken (1806) and Krieger (1810) began independent research into the development of the alimentary canal of the chick, and hit upon the right clue to the embryonic puzzle, without knowing a word about Wolff's important treatise on the same subject. They were treading in his very footsteps without suspecting it. This can be easily proved from the fact that they did not travel as far as Wolff. It was not

until Meckel crystallized into German Wolff's book on the alimentary system, and pointed out its great importance, that the eyes of anatomists and physiologists were suddenly opened. At once a number of biologists interested from embryological questions, and began to confirm Wolff's theory of epigenesis.

This renaissance of embryology and development of the epigenesis-theory was chiefly connected with the university of Wurtzburg. One of the professors there at that time was Döllinger, an eminent biologist, and father of the famous Catholic historian who later distinguished himself by his opposition to the new dogma of papal infallibility. Döllinger was both a profound thinker and an accurate observer. He took the deepest interest in embryology, and worked at it a good deal. However, he is not himself responsible for any important result in this field. In 1814 a young medical doctor, whom we may at once designate as Wolff's chief successor, Karl Ernst von Baer, came to Wurtzburg. Baer's conversations with Döllinger on embryology led to a fresh series of most extensive investigations. Döllinger had expressed a wish that some young scientific should begin again under his guidance an independent inquiry into the development of the chick during the hatching of the egg. As neither he nor Baer had money enough to pay for an incubator and the proper control of the experiments, and for a competent artist to illustrate the various stages observed, the lead of the enterprise was given to Christian Fender, a wealthy friend of Baer's, who had been induced by Baer to come to Wurtzburg. An able engraver, Chalon, was engaged to do the copper-plates. In a short time the embryology of the chick, in which Baer was taking the greatest indirect interest, was so far advanced that Fender was able to sketch the main features of it on the ground of Wolff's theory in the dissertation he published in 1817. He clearly maintained the theory of germinal layers which Wolff

but unfulfilled, and established the truth of Wall's idea of a development of the complicated systems of organs out of simple ball-shaped primitive structures. According to Pander, the ball-shaped eggs in the hen's egg divide, before the incubation has proceeded much a hour, into two deformed layers, an external arched layer and an internal annular layer, between the two there develops later a third layer, the *vesicular* (*bläschenhaft*) layer.

Hart Ernst von Haer, who had not read Pander's investigations, and had shown the greatest interest in it after Pander's departure from Würzburg, began his own much more comprehensive research by this. He published the results nearly two years afterwards in his famous work, *General Embryologie, Organismus und Entwicklung* (see introduction). This classic work still remains a model of careful observation united to real and profound speculation. The first part appeared in that the second in 1877. The book proved us to be the founders of a whole new science of embryology, but had that to our credit. It is far surpassed by modern works, and Pander in particular, that it has become, after Wall's work, the chief text of modern embryology.

After the way of the greatest scientists of the nineteenth century, and enriched by considerable additions on other branches of biology as well. He took up the theory of germinal layers, as a whole and in detail, as clearly and subtly that it has been the starting point of embryological research ever since. He taught that in all the vertebrates first two and then four of these germinal layers are formed, and that the external rudimentary organs of the body arise by the conversion of these layers into tubes. He described the first appearance of the vertebrate embryo, as it may be seen in the globular yolk of the fertilized egg, as an oval disk which first divides into two layers. From the upper or animal layer are developed all the organs which accomplish the phenomena of animal life—the functions of sensation and motion, and the arising of the body. From the lower or vegetative layer come the organs which effect the vegetative life of the organism—nutrition, digestion, blood formation, respiration, secretion, reproduction, etc.

Each of these original layers divides, according to Haer, into two thinner and superimposed layers or plates. He calls the two plates of the animal layer, the *dermo-ectoderm* and *meso-ectoderm*. From the upper of these plates, the *ectodermata*, the external skin, or rather covering of the body, the connective tissues in bones, and the sense-organs, are formed. From the lower, or mesodermata, the muscles, or fleshy parts and the bony skeleton—in a word, the entire organs—are formed. In the same way, Haer said, the lower or vegetative layer splits into two plates, which he calls the *coelo-ectoderm* and the *mesodermata*. From the outer of the two (the one which the heart, blood-vessels, spleen, and the other vascular glands, the intestines, and renal glands, are formed) from the lower or inner layer, in the vertebrates the internal and digestive organs of the alimentary canal and all its appendages, the liver, lungs, kidneys, glands, etc. Haer had in the year 1877 already judged the significance of these four embryonic germinal layers, and the solution of the conversion of them into the differentiated primitive organs with great perspicacity. He first solved the difficult problem of the transformation of the ball-like but ball-shaped, embryonic egg into the rectangular vertebrate body. Through the conversion of the layers or plates into tubes. The ball became four deformed tubes in which the rudiments of organs of the bodies of the vertebrate plates appeared in a more and more, until at last they developed into real organs. There out of the flat ecto plate is formed a hollow gut-tube, out of the flat ecto plate a hollow meso-tube, from the meso-plate a *blastula*, and so on.

Among the many great services which Haer rendered in embryology, especially vertebrate embryology, we must not forget his discovery of the human ovum. Further unexpected, as a rule, of course, assumed that man developed out of an egg, like the other animals. In fact, the preformation theory held that the germs of the whole of humanity were "laid already" in God's mind. But the real origin escaped detection until the year 1857. This was a extremely odd, being a very small circle about the city of Munich in Bavaria; it was by some under very favorable circumstances with the naked eye as a tiny particle, but in otherwise quite invisible. This particle is found in the ovary inside a much larger

* The embryo organs, right up to the point of the cell division, are all fully contained in the egg.—Haer.

phobus, which takes the name of the London College, from its discoverer, Cuvier, and had previously been regarded as the true ovum. However, in 1839 Rost proved that it was not the real ovum, which is much smaller, and is contained within the follicle. (Compare the end of the twenty-ninth chapter.)

There was also the first in showing what is known as the segmentation of the vertebrate; that is to say, the round system which first develops out of the impregnated ovum, and the thin wall of which is made up of a single layer of regular, polygonal (many-cornered) cells. (See the discussion in the twelfth chapter.) Another discovery of his that was of great importance in constructing the vertebrate stem and the characteristic organization of this vertebrate group (in a high sense belongs) was the detection of the solid rod, or the chorda dorsalis. This is a long, rigid, cylindrical rod of cartilage which runs down the longer axis of the vertebrate embryo. It appears at an early stage, and is the first sketch of the spinal column, the solid skeletal axis of the vertebrate. In the lower of the vertebrates, the amphioxus, the internal skeleton consists only of this cord throughout its life span, at the end of man and of the higher vertebrates it is found that cord that the spinal column and the brain are afterwards formed.

However, important as these and other discoveries of Rost's were in vertebrate embryology, his contributions were even more influential from the discovery that he was the first to employ the comparative method in studying the development of the animal forms. Rost occupied himself chiefly with the embryology of vertebrates (especially the fish and the bird). But he by no means confined his attention to them, gradually taking the various groups of the vertebrates into his sphere of study. As the greatest result of his comparative embryological research, Rost distinguished four different stages of development and four corresponding groups in the animal world. These chief groups or types are: 1, the vertebrates; 2, the arthropods; 3, the mollusks; and 4, all the lower groups which were then roughly comprehended under the general name of the radiata. Georges Cuvier had been the first to formulate this classification, in 1817. He showed that these groups present specific differences in their whole internal structure, and the construction and

demand of their systems of organs; and that, on the other hand, all the animals of the same type—the vertebrates—essentially agreed in their inner structure, in spite of the greater superficial differences. Rost proved that these four groups are also quite differently developed from the ovum; and that the course of embryonic forms in the same throughout for animals of the same type, but different in the case of other animals. Up to that time the chief aim in the classification of the animal kingdom was to arrange all the animals from lowest to highest, from the inanimate to man, in one long and continuous series. The organism that provided nearly everywhere that there was one unbroken chain of evolution from the lowest animal to the highest, Cuvier and Rost proved that this view was false, and that we must distinguish four totally different types of animals, on the ground of essential structure and embryonic development.

Rost's epoch-making work aroused an extraordinary and widespread interest in embryological research. Immediately afterwards we find a great number of observers at work in the early opened field, extending it in a very short time to all great groups by the various directions in which Rost's research (the admirable work of Hermann Reichenow, of Königsberg (died 1881); he made an extensive study of the embryology, not only of the vertebrates (crustaceans, insects, mollusks), but also, and particularly, of the invertebrates (Balanus, various sponges, corals, etc.). He was the first comparative student of mammalian embryology to the much renowned Wilhelm Stannius of Munich; the embryology of the rabbit (1842), the dog (1842), the guinea-pig (1842), and the deer (1842), still form classical studies. About the same time a great impetus was given to the embryology of the invertebrates. The way was opened through the obscure province by the studies of the famous Berlin zoologist, Johannes Müller, on the polychaetes. He was followed by Albert Reikner, of Würzburg, writing on the cuttlefish for the cephalopods, Siebold and Hensley on various mollusks, Fritz Müller (Dresden) on the mollusks, Wiedemann on insects, and on on. The number of workers in this field has greatly increased of late, and a quantity of new and astonishing discoveries have been made. One method, in several of them cannot work up

embryology, that their authors are too fully acquainted with comparative anatomy and evolutionary principles. Embryology is, unfortunately, a subject long neglected by many of those who otherwise, although this is improving, in some branches, most important facts in physiology, and thus also progress of very great service in embryology.

A very important advance was made by our scholars in 1858, when the cellular theory was established and a new field of inquiry bearing on embryology was suddenly opened. What the German biologist, M. Schleiden, of Bonn, showed to light with the aid of the microscope, that every plant was made up of innumerable elementary parts, which he called cells, a pupil of Johannes Müller at Berlin, Theodor Schwann, applied the discovery at once to the animal organism. He showed that in the animal body as well, with a few exceptions he thought in the nervous system was that there were everywhere to be the elementary units. At the different stages of the organism, especially the very youngest because of the greater division, he saw separated cells, groups taking, etc., very originally formed out of cells and they were one of all the elements of the plant. These cells are supposed to be living beings, that on the surface of the body which the young single-celled organism comes to be. This important discovery was based on his of carrying to embryology, do it stand a number of new questions. What is the relation of the cells to the germinal layer? Are the germinal layers composed of cells, and when a new embryo is the cells of the region that form eggs? How does the cross stand in the cellular theory? Is the yolk itself a cell, or is it composed of cells? These important questions were now opened on the embryological by the cellular theory.

The most notable effort to answer these questions—which were attacked on all sides by different students—is contained in the famous work, *Lehrbuch der Entwicklung der Thierwelt* (the translation of Robert Henslow, of Bonn, 1861). This great attempt succeeded in establishing, by a complete return of the system, the great difficulties which the cellular theory had on her way in the way of embryology. A Berlin zoologist, Carl August von Kollmer, had already attempted to explain the origin of the yolk. But this attempt was based on summary, since its own very elementary author had a small acquaintance with embryology and

the cell theory, and even with the structure and development of the tissues in particular. Henslow is largely brought order into the doubtful confusion that Schwann had created; he gave a perfectly complete explanation of the origin of the yolk, in his opinion the yolk, even in eggs, is simply a single cell, the germinal layer which develops out of it and which is composed of cells; and these cells are numerous in the germinal layer when brought from the ovulation and repeated cleaving (multiplication) of the original cellular cell, in that division into two and then into four cells; out of these four cells are more cells, these sixteen then four, and so on. Thus, in the earliest development of every animal and plant (even in the first of all out of the single-celled egg, by a repeated subdivision a factor of 2, 4, 8, 16, 32, etc.) had already shown in accordance with the reproductive cells. The cells of this group appear immediately as the first stage in the process, each of these layers is formed independently out of cells. The cells of different layers assume different shapes, forms, and different size; and in this way there is a further change in the cells, and the cells of each of the cells within the system, and from these all the different tissues of the body proceed.

There are the single beginnings of embryology, or the yolk, that stage of the development of the yolk (Henslow, 1861), it is a masterpiece by Henslow and Kollmer. Henslow, in describing more clearly the part which the different germinal layers play in the formation of the various tissues and organs, and in applying the theory of evolution to the cells and the yolk, they certainly, carried the theory of germinal layers, at least as far as it regards the vertebrates, to a high degree of perfection.

Henslow showed that three layers are formed out of the two germinal layers which compose the first single-celled embryo of the vertebrate body (the "germinal disk"), as the lower layer makes two plates. These three layers have a very definite relation to the various tissues. First of all, the cells which form the outer skin of the body (the epidermis) and its various derivatives (hair, nails, etc.) that is to say, the outer envelope of the body—are developed out of the outer or upper layer; but these are also developed in a curious way out of the same layer the cells which form the central nervous system, the

embryology," which are the direct consequences of physiological principles. What this takes to be a simple physical process—*for instance, the folding of the germinal layers for the formation of the embryonic body, embryonic tube, etc.*—is, as a matter of fact, the direct result of the growth of the various cells which form these organic structures, but these growth-movements have themselves been transmitted by heredity from parents and ancestors, and are only the hereditary expression of random physiological changes which have taken place for thousands of years in the evolution of the said organisms. Each of these histological changes was, of course, originally due to adaptation; it was, in other words, phylogenic, and attributable to morphological causes that we have described. The reason of observing them now is only, by the by-product of the system of classification that we have, an approximate idea of the organic body in this historical chain.

All the best recent research in animal embryology has led to the confirmation and development of Huxley and Huxley's theory of the germinal layers. One of the most important additions is the discovery of two new layers, the discovery that the two primary layers out of which is built the body of all vertebrates (including man) are also present in all the invertebrates, with the sole exception of the lowest group, the radiolarian protozoa. Huxley had detected them in the nudibranch in 1859. He showed that the two layers of cells from which the body of this animal is developed correspond, both morphologically and physiologically, to the two original germinal layers of the vertebrates. The outer layer, from which come the external skin and the muscles, was then called by Huxley (1859) the "ectoderm" (=outer layer, or skin); the inner layer, which forms the alimentary and reproductive organs, was called the "enteroderm" (=inner layer). In 1865 and the following years the discovery of the germinal layers was extended to other groups of the invertebrates. In particular, the zoologist R. V. Brown (1865), Huxley (1865), stated them in all the main diverse groups of the invertebrates—the coelom, molluscs, arthropods, annelids, etc.

In my monograph on the sponges (1873) I proved that these two primary germinal layers can also be found in that group, and

that they may be traced from a right up to man, through all the various classes, to identical form. This "homology of the two primary germinal layers" extends through the whole of the animal, or rather, through the whole animal kingdom, with the sole exception of its lowest members, the radiolarian beings, or protozoa. Those truly organized animals do not have germinal layers, and therefore do not extend to forming true tissues. Their whole body consists of a single cell (as is the case with the amoeba and infusoria), or of a loose aggregation of only slightly differentiated cells, though it may not even reach the full structure of a single cell (as with the sponges). But in all other animals the inner first grows into two primary layers, the inner or *ectoderm* (the ectoderm, epidermis, or cuticle), and the inner or *enteroderm* (the enteroderm, hypodermis, or endoderm), and from these the various and organs are formed. The first and oldest organ of all these organisms is the primitive gut for protection and in opening the primary mouth (stomach). The typical embryonic form of the stomach, or *enteroderm*, is called by the simple expression of the invertebrate body in called the *gastrostoma*. It is to be compared to the homology representation of some primitive common ancestor of the animals, which we call the *gastrostoma*. The origin of the sponges and other simple, and to the stomach, the sponges, invertebrates, arthropods, and vertebrates. All these animals may be compared under the general heading of "gut animals," or *gastrostoma*, in contradistinction to the gutless protozoa.

I have pointed out in my *Study of the Gastric Theory* (just mentioned) (1873) the important consequences of this comparison in the morphology and classification of the animal world. I also divided the realm of animals into two great groups, the lower and higher animals. In the first are comprised the invertebrate (so-called zoophytes, or "plant-animals"). In the lower forms of this group the body consists throughout its whole of the primary germinal layers with the sole exception of the sponges and protozoa (as differentiated). But with the higher forms of the invertebrates (the coelom, higher animals, arthropods, and vertebrates) a middle layer, or *mesoderm*, from of differentiated cells, is developed between the

either two layers; but blast and an internal cavity are still lacking.

To the usual great group of the mammal I gave the name of the ambion, or blastula for the bilateral higher forms. They all have a cavity within the body (somata), and most of them have blast and blast cavity. In this are comprised the six higher series of the animal kingdom, the cestodes and their descendants, the molluscs, arthropods, annelids, tunicates, and vertebrates. In all these bilateral organisms the two-sided body is formed out of four secondary germinal layers, of which the inner two constitute the wall of the embryonic cavity, and the outer two the wall of the body. Moreover the two parts of layers form the cavity (somata).

Although I had special views on the great developmental importance of the cavity in the study of the Cnidaria, Flourens, and independently in proving the degeneration of the four secondary germinal layers in the organization of the cestodes I was unable to deal satisfactorily with the difficult questions of the mode of their origin. This was done eight, more often twelve by the German Cnidaria and the British Flourens in their careful and extensive descriptive studies in their study of the Cnidaria. An attempt in English in the *Middle German Layer* (not translated) (1881) they showed that in most of the Cnidaria, especially in all the vertebrates the body cavity comes in the form of a, by the outgrowth of the outer blast the inner layer. These two comparisons proved from the embryonic origin of the germinal layers between the two primary layers. The outer part of the outgrowth, which forms the dorsal layer, also adds to the ventral; the outer blast (ventral layer) unites with the ventral. Thus are formed the double-layered gut-wall cavity and the double-layered body-wall cavity, and between the two is formed the cavity of the cavity, by the blending of the right and left outgrowths. We shall see this more fully in Chap. X.

The many new pairs of liver and back blast suggested by my germinal theory and Haeckel's cavity theory led to the publication of a number of writings on the theory of germinal layers. Most of them are not to appear at all first, but in the end the majority supported it. Of late years back theories are accepted in their essential features by nearly every competent man of science, and light and order

have been introduced into this once dark and contradictory field of research. A further cause of conservatism for this subject of the great embryological discovery is that it brought with it a simplification of the mind for physiognomic study and explanation.

Lawrence and practice in embryological research have been remarkably advanced during the past thirty years by the application of physiological methods. Hundreds of specimens and even thousands of new organs in the development of comparative embryology and its establishment as a branch of medicine, whereas they numbered only a few dozen not many decades ago. It would take too long to enumerate even the most important of the scientific works which have since had embryological importance since that time. References to these will be found in the last chapters of embryology of Kollman, Haeckel, Marrow, Kollman, Kollman, and Haeckel.

Kollman's *Developmental Biology des Menschen und der Thiere* (The First Series of a Book appeared thirty-two years ago, and the new series of that time of gathering into perspective here the cultural importance of the system, and expanding them in some part of our, all the books of the cellular theory and the theory of germinal layers. Unfortunately, the developmental theory was somewhat, to which comparative anatomy, histology, and physiology, were so much, as applied to the theory of descent generally and to Darwinism in particular. As the other research I have mentioned since a doublet of the subject. Francis Haeckel has carefully collected and presented with discrimination in his *Manual of Comparative Embryology* (1891) the very scattered and extensive literature of the subject; he has also exposed the basis of the germinal theory by a comparative description of the origin of the organs from the germinal layers in all the great groups of the animal kingdom, and has given a most thorough account, support in the principles I have described. A comparison of his work with the excellent *Four-Book of the Embryology of the Vertebrates* (1891) [translating 1891] of Kollman and Haeckel shows what astonishing progress has been made in the science in the course of two years. I would especially recommend the manuals of Julius Kollman and Oscar Haeckel to those students who are interested in further study by these chapters on human

embryology. Kollmer's readable for its clear presentation of the subject and very fine original illustrations; its author adheres firmly to the biogenetic law, and uses it throughout with considerable profit. That is not the case in Oscar Hertwig's recent *Treatise of the Embryology of Man and the Mammals* (transl. 1892 and 1899) (seventh edition, 1903). This able anatomist has of late often been quoted as an opponent of the biogenetic law, although he himself had demon-

strated that the oscillation is partly due to the middle of the series. As with regard to hypotheses; though it is quite impossible to make any headway in the explanation of facts without them. However, the purely descriptive part of embryology in Hertwig's *Treatise* is very thorough and reliable.

A new branch of embryological research has been studied very successfully in the last decade of the nineteenth century—namely, "experimental embryology." The great importance which has been attached to the application of physical experiments to the living organism for the last hundred years, and the valuable results that it has given to physiology in the study of the vital phenomena, have led to extension to embryology. I was the first to make experiments of this kind during a stay of four months on the Canary Island, Lanzarote, in 1866. I there made a thorough investigation of the almost unknown embryology of the aiphanophorids. I cut a number of the embryos of these animals (which develop freely in the water, and pass through a very curious transformation), at an early stage, into several pieces, and found that a fresh organism (more or less complete,

according to the size of the piece) was developed from each particle. More recently some of my pupils have made similar experiments with the embryos of vertebrates (especially the frog) and some of the invertebrates. Wilhelm Roux, in 1878, has made extensive experiments, and based on them a special "mechanical embryology," which has given rise to a good deal of discussion and controversy. Roux has published a special journal for these subjects since the *Archiv für Naturgeschichte*.

The contributions

very many of them are valuable papers on the physiology and pathology of the embryo. Pathological experiments—the placing of the embryo in abnormal conditions—have yielded many interesting results; just as the physiology of the normal body has for a long time derived assistance from the pathology of the diseased organism. One of these mechanical-embryological articles refers to the erroneous methods of Hux, and are very misleading. It must be said of the many contributions of mechanical embryology which take up a portion of loyalty to the theory of descent and its chief embryological foundation—the biogenetic law. This law, however, once rightly understood, is not opposed to, but is the best and most solid support of, a sound mechanical embryology. Impartial reflection and a due attention to paleontology and comparative anatomy should convince those opposed to mechanicism that the facts they have discovered—and, indeed, the whole embryological process—cannot be fully understood without the theory of descent and the biogenetic law.

CHAPTER IV.

THE OLDER PHYLOGENY

The embryology of man and the animals, the history of which we have reviewed in the last two chapters, was mainly a descriptive science forty years ago. The earlier investigations in this province were

chiefly directed to the discovery, by careful observation, of the wonderful facts of the embryonic development of the animal body from the ovum. Forty years ago we may almost attack the question of the

course of these phenomena. For fully a century, from the year 1790, when Wolff's solid *Pharus gonostomus* appeared, until 1859, when Darwin published his famous *Origin of Species*, the real course of the embryonic processes were quite unknown. The one thought of seeking 'the agencies that effected this marvellous succession of processes. The task was thought to be as difficult as almost as pure beyond the limits of human thought. It was reserved for Charles Darwin to initiate us into the knowledge of these causes. The completion to migration in this great genius, who brought a religious revolution in the whole field of biology a founder at the same time of a new period in contemporary life. It is true that therein occupied himself very little work short embryological research, and even in his chief work he only touches incidentally on the embryonic phenomena. But in his reform of the theory of descent and the founding of the theory of selection he has given us the means of attaining to a real knowledge of the causes of embryonic formation. That is, in my opinion, the chief factor in Darwin's incalculable influence on the whole science of evolution.

When we turn our attention to the latest period of embryological research, we pass into the narrow domain of organic production—stomatogenesis, or phylogeny. I have already indicated in the first chapter the important and intimate causal connection between these two sciences of the science of development: between the production of the individual and that of his structure. We have formulated this connection in the biogenetic law, the shorter evolution, that of the individual, or ontogenesis, is a rapid and necessary repetition, a condensed recapitulation of the larger evolution, or that of the species. In this principle we express all the essential points relating to the causes of evolution; and we shall keep throughout this work to confirm this principle and lend it the support of facts. When we look to its actual significance, perhaps it would be better to formulate the biogenetic law thus: "The evolution of the species and the stem (*Aphele*) shows us, in the phylogenetic functions of heredity and adaptation, the conditioning forces in which the evolution of the individual depends"; or, more briefly: "Phylogenesis is the mechanical cause of ontogenesis."

embodiment by which Darwin revealed the causes of evolution to us, we must glance at the effects of earlier scientific ideas. Our historical inquiry into them will be even shorter than that into the work done in the field of ontogeny. We have very few names to consider here. At the head of them we find the great French naturalist, Jussieu Lamarck, who has established ontogeny as a general theory in this. Even before his time, however, the great philosopher, Kant, and the great poet, Goethe, of Germany had occupied themselves with the subject. But these efforts passed almost without recognition in the eighteenth century. A "philosophy of nature" did not even start the beginning of the nineteenth century. In the middle of the same century there was not a single attempt to solve seriously the question of the origin of species, which is the evolutionary point of phylogeny. On all sides it was regarded as an insoluble riddle.

The whole science of the evolution of man and the other animals is intimately connected with the question of the origin of species, or with the problem of the origin of the various animals which we group together under the name of species. Thus the solution of the species question is important. It is well known that this solution was given by Lamarck, who, in his *Systeme Biologique Naturel* (1796), the first to classify and name the various groups of animals and plants and draw up an orderly system of the species then known. Since that time "species" has been the most important and indispensable idea in descriptive natural history, in zoology, and botanical classification, although there have been sufficient controversies as to its real meaning.

When, then, is this "organic species"? Lamarck himself approached directly to the biogenetic narrative. He believed that, as it is stated in Genesis, one pair of each species of animals and plants was created on the beginning, and that all the individuals of each species are the descendants of these created couples. As for the inheritance of characteristics that have made one form of organs in one being, he thought it sufficient to require the constant of one and the same, since this would be fully sufficient to propagate in species. Further developing these views Lamarck went on to interpret from Genesis the account of the deluge and of Noah's ark as a natural law of the conservation of the

and topographical distribution of organisms. He accepted the story that all the plants, animals, and even on the earth were swept away in a universal deluge except the couples preserved with Noah in the ark, and ultimately landed on Mount Ararat. This massacre seemed to him particularly suitable for the landing, as it reaches a height of more than eleven feet, and thus provides in its higher zones the several climates demanded by the various species of animals and plants. The animals that were unaccounted to a cold climate would remain at the summit; they need in a warm climate could descend to the foot; and those requiring a temperate climate could remain half-way down. From this point the repopulation of the earth with animals and plants could proceed.

It was strikingly to have an explanation of the accepted of evolution in Liess's view, as one of the chief sources of information, paleontology, was not a fully unknown. The science of the fossil remains of ancient animals and plants is very closely bound up with the whole question of evolution. It is impossible to explain the origin of living organisms without appealing to it. But this science did not rise with a much later date. The real impetus of scientific paleontology was Georges Cuvier, the great distinguished biologist who, after Liess, worked at the reconstruction of the animal world, and effected a complete revolution in systematic zoology at the beginning of the nineteenth century. In regard to the nature of the species he introduced himself with Liess and the Mosaic story of creation, though this was more difficult for him with his acquaintance with fossil remains. He clearly showed that a number of quite different animal populations have lived on the earth; and he claimed that we must distinguish a number of stages in the history of our planet, each of which was characterized by a special population of animals and plants. These successive populations were, he said, quite independent of each other, and therefore the supernatural creative act, which was demanded in the origin of the animals and plants by the dominant view, must have been repeated several times. In this way a whole series of different creative periods must have succeeded each other; and in connection with them he had to assume that successive univer-

sal or cataclysmic something like the legendary deluge—must have taken place repeatedly. Liess was all the more interested in these catastrophes or cataclysms as geology was just beginning to assert itself, and great progress was being made in our knowledge of the structure and formation of the earth's crust. The various strata of the earth were being carefully examined, especially by the German geologist Werner and his school, and the fossils found in them were being classified, and their occurrence also studied to point to a variety of something possible. In each period the earth's crust, composed of the various strata, seemed to be differently constituted, just like the population of animals and plants that lived upon it. Cuvier attributed this variation to the results of his own paleontological and geological research, and in his effort to give a reasonable view of the whole process of the earth's history he came to form the theory which is known as "the catastrophist theory," or the theory of terrestrial revolutions. According to this theory, there have been a series of mighty earthquakes on the earth, and these have suddenly destroyed the whole animal and plant population. In so far as it was such a theory, it was not a fresh creation of living things throughout the earth. As the creation could not be continued by natural laws, it was necessary to appeal to an intervention on the part of the Creator. The catastrophist theory which Liess described in a special work, has been generally accepted, and retained its position in biology for half a century.

However, Liess's theory was completely overturned sixty years ago by the geologists led by Charles Lyell, the most distinguished worker in the field of geology. Lyell proved in his famous *Principles of Geology* (1830) that the theory was false, in so far as it conceived the crust of the earth; that it was really unnecessary to bring in supernatural agencies or general catastrophes in order to explain the structure and formation of the crust; and that we can explain them by the law of the agencies which are at work today in working and reconstructing the surface of the earth. These agencies are—the action of the atmosphere and water in its various forms (snow, ice, fog, rain, the wear of the shore, and the moving masses), and the volcanic action which is caused by the action of the

them. I still confidently prove that these ancient causes are quite adequate to explain every feature in the build and formation of the crust. Huxley's theory of entelechy was very soon driven out of the province of geology, though it remained for another thirty years in undisputed authority in biology. All the embryologists and biologists who gave any thought to the question of the origin of organisms adhered to Cuvier's overweening idea of revolutions and new creations.

In order to liberate the complete antiquity of biology from this old idea on the question of the origin of the various species of animals and plants, I may say, from my own experience, that during the whole of my own early studies I was as ignorant as a negro word upon this most important problem of the nature. I was ignorant enough at that time (1845-1850) to take the most daring and violent for every matter of biological nature. But one of them was concerned the question of the origin of species. But a word was over and then the earlier efforts to understand the formation of living things, as about Lamarck's *Philosophie Zoologique* which had made a fresh attack on the problem in 1809. Hence it is easy to understand the enormous opposition that Darwin encountered when he took up the question for the first time. His words turned to dust in the air, a liberal a single serious effort to suggest them. The whole question of the formation of living things was considered by biologists, until 1859, as pertaining to the province of religion and history, not science, even in speculative philosophy in which the question had been approached from various sides, we can find no trace of a genuine scientific treatment. This is due to the dualistic system of Immanuel Kant, who taught a natural system of evolution as far as the inorganic world was concerned, but, on the whole, adopted a supernatural system as regards the origin of living things. He even went so far as to say: "It is quite certain that we cannot even satisfactorily understand, much less explain, the nature of an organism and its internal forces on purely mechanical principles: it is so certain, indeed, that we may confidently say 'It is shown for a time to imagine now that some day a Newton will arise who will explain the origin of a living being of plants by natural laws not controlled by design'—such a hope is entirely forbidden us." In these

words Kant definitely closes the scientific and rational path of view for biological sciences.

Nevertheless, Kant deserted this path of view at times, particularly in several remarkable passages which I have dealt with at length in my *Natural History of Creation* (chap. 7), where he expresses himself in the opposite, or materialistic, sense. In fact, these passages would justify one, as I showed, in claiming his support for the theory of evolution. However, these materialistic passages are only stray glances at light; as a rule, Kant adheres to biology to the extreme dualistic ideas, according to which the forces of work in inorganic nature are quite different from those of the organic world. This dualistic system prevails in academic philosophy to-day—most of our philosophers still repeating these two processes as totally distinct. They put, on the one side, the organism or "nature" world, in which there are in each only mechanical laws, acting necessarily and without design; and, on the other, the free area of organic nature, in which none of the phenomena can be properly understood, either as regards their inner nature or their origin, except in the light of supernatural design, created out by God in purposeful nature.

The prevalence of this unfortunate dualistic prejudice prevents the problem of the origin of species, and the connected question of the origin of man, from being regarded by the bulk of people as a scientific question at all until 1859. Nevertheless, a few distinguished students, free from the current prejudice, began, at the commencement of the nineteenth century, to make a serious attack on the problem. The work of these attaches particularly to what is known as "the older school of natural philosophy," which has been so much misrepresented, and which included Jean Lamarck, Buffon, Geoffroy St. Hilaire, and Blainville in France, Wolfgang Goethe, Reinhold Trewan, Schelling, and Lamarck's Opponent in Germany (Hilf, *Erkenntnis Darwin in England*).

The great natural philosopher who created this difficult question with the greatest sagacity and unprejudicedness was Jean Lamarck. He was born at Bazemont, in Flanders, on August 18, 1744; he was the son of a clergyman, and was devoted to the Church. But he turned to such glory in the end, and eventually devoted himself to science.

The *Philosophie Zoologique* was the

But scientific attempts to sketch the real course of the origin of species, the first "natural history of evolution" of plants, animals, and men. But, as in the case of Wolf's work, they remarkably often work but on abstracted subjects; neither can any the other could obtain any recognition from their professional contemporaries. The aim of science was mistaken to take as historic in the work, and to develop the genus is considered of the most important biological truths. The most distinguished biologists and zoologists entirely rejected it, and did not even dignify to reply to it. Cuvier, who lived and worked in the same city, has not thought it to devote a single syllable to this great achievement in his enormous progress in the science, in which the present observations found a place in short. Lamarck's *Philosophie Zoologique* shared the fate of Wolf's theory of development, and was for half a century ignored and forgotten. The theories of evolution, especially Oken and Goethe, who were occupied with similar speculations at the same time, seem to have known nothing about Lamarck's work. If they had known it, they would have been greatly helped by it, and might have carried the theory of evolution much further than they found it possible to do.

To give an idea of the great importance of the *Philosophie Zoologique*, I will briefly explain Lamarck's leading thoughts. He held that there was no essential difference between living and human beings. That one is one united and connected system of phenomena; and the forces which produce the infinite bodies are the only ones at work in the kingdom of living things. We have, therefore, to use the same method of investigation and explanation in both domains. Life is only a physical phenomenon. All the plants and animals, with man at their head, are to be explained, in structure and life, by mechanical or physical causes, without any appeal to final causes, just as in the case of minerals and other inorganic bodies. This applies equally to the origin of the various species. We must not assume any original creation, or assumed creation (as in Cuvier's theory), to explain this, but a natural, continuous, and necessary evolution. The whole evolutionary process has been interrupted. All the different kinds of animals and plants which are now existing, as they have ever been, have descended in a natural way from earlier and different

species; all arose from one common stock, or from a few common ancestors. There remains necessary must have been quite simple beginnings of the lowest type, arising by spontaneous generation from inorganic matter. The succeeding species have been constantly modified by adaptation to their varying environment (especially by use and habit), and have transmitted their modifications to their successors by heredity.

Lamarck was the first to formulate as a scientific theory the natural origin of living things, including man, and to push the theory to its extreme consequences—the rise of the highest organisms by spontaneous generation (or a long series) and the descent of man from the common nearest mammal (the ape). He sought to explain this last point in both a physical and metaphysical way, in the same agreeing a birth by descent as a law in the natural origin of the plant and animal kingdoms. He considered use and habit (adaptation) on the one hand, and heredity on the other, to be the chief of these agencies. The most important modifications of the origin of plants and animals are due in his opinion, to the formation of their very organs, or to the use or disuse of them. To give a few examples: the woodpecker and the hummingbird have got their peculiarly long tongues from the habit of extracting their food with their tongues stuck deep into narrow holes in bark; the bird has developed in its life into its long life on a mountain, the grackle has lengthened his neck by stretching up to the highest branches of trees, and so on. It is quite certain that the use or disuse of organs is a most important factor in organic development, but it is not sufficient to explain the origin of species.

To adaptation we must add heredity as the second and not less important agency, as Lamarck perfectly comprehended. He said that the modification of the organs in any one body acted by use or disuse was slight, but that it was increased by transmission in passing by heredity from generation to generation. But he missed altogether the principle which Darwin afterwards found to be the chief factor in the theory of transformation—namely, the principle of natural selection in the struggle for existence. It was partly owing to his failure to detect this supremely important element, and partly to the poor condition of all biological science at the time, that Lamarck did not

succeed in establishing more firmly his theory of the common descent of man and the other animals.

Independently of Lamarck, the older German school of natural philosophy, especially Reinhold Trevisan, in his *Metaphysik* (1800), and Lorenz Oken, in his *Metaphysik* (1804), turned its attention to the problem of evolution about the end of the eighteenth and beginning of the nineteenth century. I have described its work in my *History of Creation* (chap. 19). Here I can only deal with the brilliant genius whose evolutionary ideas are of special interest—the genius of German poets, Wolfgang Goethe. With his keen eye for the beauties of nature, and his profound insight into its life, Goethe was early attracted to the study of various natural systems. It was the Livonian occupation of his leisure hours throughout life. He gave particular and persistent attention to the theory of colours. But the most valuable of his scientific studies are those which relate to that "living, glorious, precious thing," the organism. He made profound research into the science of structures or morphology (morphos = form). Here, with the aid of comparative anatomy, he obtained the most brilliant results, and went far in advance of his time. His research, in particular, his systematic theory of the skull, his discovery of the potential gland in man, his studies of the metamorphosis of plants, etc. These morphological studies led Goethe on to research into the homologies and modifications of organic structures which we now regard as the first germs of the science of evolution. He approached us near to the theory of descent that we now regard him, after Lamarck, as one of its earliest founders. It is true that the poet stimulated a complete scientific theory of evolution, but we find a number of remarkable suggestions of it in his splendid miscellaneous essays on morphology. Some of them are really among the very basic ideas of the science of evolution. He says, for instance (allg.) "When we compare plants and animals in their most rudimentary forms, it is almost impossible to distinguish between

them. But we may say that the plants and animals, beginning with an almost inseparable closeness, gradually advance along two divergent lines, until the plant at last grows in the solid, enduring tree and the animal attains in man to the highest degree of mobility and freedom." That Goethe was not merely speaking in a poetical, but in a literal genealogical, sense of this close affinity of organic forms is clear from other remarkable passages in which he treats of their variety in structural form and unity in internal structure. He declares that every living thing has arisen by the interaction of two opposing formative forces or impulses. The internal or "centripetal" force, the type or "impulse to specification," tends to maintain the continuity of the specific forms in the succession of generations—*conservation*. The external or "centrifugal" force, the element of variation or "impulse to metamorphosis," is continuously modifying the species by changing their environment, this is *adaptation*. In these significant conceptions Goethe approaches very close to a recognition of the two great mechanical factors which we now regard as the chief causes of the formation of species.

There over, in order to appreciate Goethe's views on morphology, we must associate his decidedly pantheistic conception of nature with his pantheistic philosophy. The above and born intimate with which he followed on two last years, the controversy of contemporary French scientists, and especially the struggle between Cuvier and Geoffroy, de Saint-Iris (see chap. 15 of *The History of Creation*), is very characteristic. It is also necessary to be familiar with his style and general manner of thought in order to appreciate rightly the many allusions to evolution found in his writings. Otherwise, one is apt to make serious errors.

He approached so close, at the end of the eighteenth century, to the principles of the science of evolution that he may well be described as the first forerunner of Darwin, although he did not go so far as to formulate evolution as a scientific system, as Lamarck did.

CHAPTER V.

THE MODERN SCIENCE OF EVOLUTION

We owe so much of the progress of scientific knowledge to Darwin's *Origin of Species* that its influence is almost without parallel in the history of science. The literature of Darwinism grows from day to day, not only on the side of scientific zoology and botany, the sciences which were chiefly affected by Darwin's theory, but in a far wider sphere, so that we find Darwinism almost in popular literature with a vigour and even that originality in no other scientific conception.

This remarkable success is due chiefly to two circumstances. In the first place, all the sciences, and especially biology, have made astounding progress in the last half-century, and have furnished a very large quantity of proofs of the theory of evolution. (A striking contrast to the failure of Lamarck and the other scientists to attract attention to their efforts to explain the origin of living things and of man, we have this second and successful effort of Darwin, which was able to gather to its support a large number of established facts. Availing himself of the progress already made, he had very different scientific proofs to allege than Lamarck, or de Meisere, or Goethe, or Treviranus had had but, in the second place, we must acknowledge that Darwin had the special advantage of approaching the subject from an entirely new side, and of basing the theory of descent on a consistent system, which now goes by the name of Darwinism.

Lamarck had unsuccessfully attempted to explain the modification of organisms that descend from a common form chiefly by the action of habit and the use of organs, though with the aid of heredity. But Darwin's success was complete when he independently sought to give a mechanical explanation, on a quite new ground, of this modification of plant and animal structures by adaptation and heredity. He was involved in his theory of selection on the following grounds. He compared the origin of the various kinds of animals and plants which we modify artificially—by the action of

artificial selection in horticulture and among domestic animals—with the origin of the species of animals and plants in their natural state. He then found that the agencies which we employ in the modification of forms by artificial selection are also at work in Nature. The chief of these agencies he held to be "the struggle for life." The gist of this peculiarly Darwinian idea is given in this formula: "The struggle for existence produces new species without premeditated design in the life of things, in the same way that the will of man rationally selects new races of artificial quadrupeds." The grandeur of the further idea of forms as he wills for his own profit, by ingeniously using the agency of heredity and adaptation for the modification of structures; so, in the natural state, the struggle for life is always unconsciously modifying the various species of living things. This struggle for life, or competition of organisms in securing the means of subsistence, acts without any conscious design, but it is done the less effective in modifying structures. As heredity and adaptation enter into the chosen reciprocal action under his influence, new structures, or modifications of structure, are produced, and these are purposive in the sense that they serve the organism when formed, but they were produced without any pre-conceived aim.

This simple idea is the central thought of Darwinism, or the theory of selection. Darwin conceived this idea at an early date, and then, for more than twenty years, worked at the collection of empirical evidence in support of it before he published his theory. His grandfather, Erasmus Darwin, was an able scientist of the older school of natural philosophy, who published a number of natural-philosophic works about the end of the eighteenth century. The most important of them is his *Zoonomia*, published in 1794, in which he expounds views similar to those of Goethe and Lamarck, without really inventing anything of the work of these

misapprehension. However, in the writings of the geologists the hypothesis is mentioned rather than the judgment, while in Charles Darwin the two were latter balanced.

Darwin did not publish any account of his theory until 1859, when Alfred Russel Wallace, who had independently reached the same theory of selection, published his own work. In the following year appeared the *Origin of Species*, in which he developed his argument in all length and supports it with a mass of proof. Wallace had reached the same conclusion, but he had not as clear a perception as Darwin of the effectiveness of natural selection in forming species, and did not develop the theory as fully. Nevertheless, Wallace's writings, especially those on man, are an admirable work on *The Geographical Distribution of Animals*, contain many fine original contributions to the theory of selection. Unfortunately, this gifted specialist has since devoted himself to apiculture!

Darwin's *Origin of Species* had an extraordinary influence, though not at first on the experts of the science. It took zoologists and botanists several years to recover from the astonishment into which they had been thrown at the revolutionary idea of the work. But its influence on the general reader, and which we emphasize, and but which we emphasize has remained from year to year, is far-reaching. A most healthy fermentation is now taking place in biology, especially in comparative anatomy and embryology, and in geological and historical classification. In this way it has brought about almost a revolution in the prevailing views.

However, the point which finally convinced us here—the students of the theory to men—first and foremost of all in Darwin's first work in 1859, it was believed for several years that he had no thought of applying his principles to man, but that he showed the current idea of man holding a special position in the universe. Not only prominent biologists (especially several physiologists) but also a number of men of science, made very early that Darwinism in itself was not to be applied; that it was quite right to use it to explain the origin of the various

species of plants and animals, but that it was totally inapplicable to man.

In the meantime, however, it seemed to a good many thoughtful people, laymen as well as scientists, that (his was wrong) that the descent of man from some other animal species, and immediately from some ape-like mammal, followed logically and necessarily from Darwin's reformulated theory of evolution. Many of the most opponents of the theory now at once the justice of this position, and, as this opposition was insubstantial, they seemed to get rid of the whole theory.

The first scientific application of the Darwinian theory to man was made by Huxley, the greatest biologist in England. This able and learned scientist, to whom history owes much of its progress, published in 1863 a small work entitled *Man's Place in Nature*. In the extremely important and interesting lecture which made up this work he pointed clearly that the descent of man from the ape followed necessarily from the theory of descent. If that theory is true, we are bound to search for the animal to which most closely resemble man as those from which humanity has been gradually evolved. About the same time Carl Vogt published a larger work on the same subject. We must also mention Gustav Jaeger and Friedrich Haeckel among the students who supported and brought the theory of evolution (necessarily) after the publication of Darwin's book, and maintained that the descent of man from the lower animals logically followed from it. The former published, in 1866 a work on the origin and position of man.

About the same time I attempted, in the second volume of my *General History of Man*, to apply the theory of evolution to the whole organic kingdom, including man. I endeavored to establish the systematic connectedness of the various classes of the animal world, the protists, and the plants, as it seemed necessary to do up Darwinian principles, and as we can actually do so with a high degree of confidence. If the theory of descent, which Lamarck first clearly formulated and Darwin thoroughly established, is true, we should be able to draw up a natural classification of plants and animals in the light of their genealogy, and to connect the large and small divisions of

* Huxley and Vogt applied it to the theory of the origin of man, and Huxley applied it to the theory of the origin of the whole organic kingdom.

* Huxley applied it to the theory of the origin of the whole organic kingdom.

the system as the foundation and basis of an assumed law. The eight pre-embryological tables which I inserted in the second volume of the *General Morphology* are the first sketches of their kind. In the second-volume chapter, particularly, I trace the chief stages in man's ancestry, as far as it is possible to follow it through the vertebrate stem. I tried especially to determine, as well as one could at that time, the position of man in the classification of the mammalia and in pre-embryological significance. I have greatly simplified this attempt, and treated it in a more popular form, in chapter xxvi-viii of my *History of Creation* (1881).

It was not until 1875, twelve years after the appearance of *The Origin of Species*, that Darwin published the *Lectures* which made the much-needed application of his theory to man, and revealed the extended ancestry of his species. This important work was *The Descent of Man, and Selection in Relation to Man*. In this I gave in separate parts the conclusions, with numerous facts, that man also must have been developed out of lower species, and described the important part played in sexual selection in the elevation of man and the other higher animals. He insisted that the careful selection which the lower animals in each sex in regard to sexual relations and procreation, and the analogous function in the higher animals, develop through them, one of the greatest departures in the pre-embryological development of forms and the differentiation of the sexes. The male choosing the best-developed females in case of animals, and the female choosing only the best-developed males in man, the special features and the sexual characteristics are everywhere accentuated. In fact, some of the higher animals develop in this manner a few traits and judgments that must be noted. But, even so regarded, it is in the sexual selection that we see the basis only, which is the chief foundation of civilization. The rise of the human race is due for the most part to the advanced sexual selection which our ancestors exercised in choosing their mates.

Darwin accepted as the main the general outlines of man's assumed law, so I gave it in the *General Morphology* and the *History of Creation*, and advanced that the

science had led to the new conclusion. That he did not at once apply the theory to man in his first work was a commercial-like piece of discretion, such a step was bound to excite the dangerous opposition to the whole theory. The first thing to do was to establish it in regard to animal and plant worlds. The subsequent extension to man was bound to be made sooner or later.

It is important to understand this very clearly. If all living things came from a common root, man must be included in the general system of evolution. On the other hand, if the human species were separately created, man, like most birds, must be excluded, and not even the laws to choose between them the separation. This cannot be too frequently or too strongly emphasized. After all the system of animal- and plant-world is a separate origin created, not created and in that case man and the remainder of a creative act in religious teaching, or the different species have been created from a few common, simple ancestral forms, and so that man must be the highest fruit of the tree of evolution.

We may also see briefly at the following principle - The descent of man from the lower animals is a special derivation which can never follow from the general evolution law of the whole theory of evolution. In this principle we have a clear and plain statement of the matter. Evolution is in reality nothing but a great unknown, which we are compelled to make in the comparative study of the other organisms (laws of morphology and physiology). But as most of us are contented according to the laws of evolution, and are content to determine scientific truth by direct observation and comparison of observation. In the study of living things we can scarcely ever directly and fully, and with mathematical accuracy, determine the nature of phenomena, or in them in the simplest study of the inorganic world - in chemistry, physics, meteorology, and astronomy. In the latter, especially, we can always use the simplest and absolutely exact method - that of mathematical determination. But in biology this is quite impossible for various reasons - one very obvious reason being that some of the facts of the sciences are very complicated and much less intricate to show a great mathematical outline. The greater part of the phenomena that biology deals with are

1. Of this I have not the space to say, but I have said it in the past.

complexed historical process, which are related to a far-reaching past, and as a rule can only be explained clearly estimated. Hence we have to proceed by induction—that is to say to draw general conclusions, stage by stage, and with proper scientific caution, from the accumulation of detailed observations. These inductive conclusions cannot command absolute confidence, like mathematical axioms, but they approach the truth, and gain increasing probability, in proportion as we extend the scope of observed facts on which we build. The importance of these inductive facts is not diminished from the circumstances that they are based upon merely on temporary acquisitions of science, and may be integrated to any extent in the progress of scientific knowledge. The same may be said of the inductiveness of many other sciences, such as geology or archaeology. However small this may be allowed and improved in detail at the course of time, their inductive truth may secure their undiminished usefulness.

Now when we see that the science of progress in the sense of Lamarck and Darwin is an inductive one—in fact, the product of all biological induction—so to say, in the first place, on the facts of paleontology. This science gives us some direct acquaintance with the historical phenomena of the changes of species. From the records in which we find the fossils in the various strata of the earth we gather confidently, in the first place, that the living populations of the earth have gradually developed, or evolved, on the earth's crust itself, and that, in the second place, several different populations have succeeded each other in the various geological periods. Modern geologists maintain that the formation of the earth has been gradual, and undisturbed in any radical revolution. And a few we compare together the various kinds of animals and plants which succeed each other in the history of our planet, we find, in the first place, a continuous and gradual increase in the number of species from the earliest days until the present day; and, in the second place, we notice that the forms in each great group of animals and plants also constantly increase in the ages which are. Thus, of the vertebrates there are at first only the lower fishes; then come the higher fishes, and later the amphibians. Still later appear the three higher classes of vertebrates—the reptiles,

birds, and mammals, for the first time only the lowest and least perfect forms of the mammals are found at first; and it is only as a very late period that placental mammals appear, and then belongs to the most and youngest branch of them. Two particular of form innovations as well as variety, from the earliest to the latest stage. Thus is a list of the greatest importance. It can only be explained by the theory of evolution, such which it is an perfect harmony. If the different groups of plants and animals do really descend from such others, we must expect a sort of increasing in their number and perfection under the influence of natural selection, just as the mechanism of fossils actually discloses it to us.

Comparative anatomy, furnished several series of facts which are of great importance for the forming of our induction. The branch of morphology compares the actual structures of living things and works in the great variety of organic forms the main and complete law of organization, or the common type or structure. Ernst Haeckel founded this science in the beginning of the nineteenth century it has been a favorite study of the most distinguished scientists. Even before Darwin's time George had been greatly stimulated by it, and induced to take up the study of morphology. Comparative anatomy, in this comprehensive study and comparison of the many details of the variousness—some of its most interesting sections—especially interested him, and led him to form the theory of the world which I mentioned before. Comparative anatomy shows that the external structure of the animals of each class and the plants of each class is the same as its essential features, however much they differ in external appearance. Thus man has as great a resemblance in the chief features of his internal organization to the other mammals that no comparative anatomist has ever doubted that he belongs to them class. The whole internal structure of the human body, the arrangement of its various systems of organs, the distribution of the bones, muscles, blood-vessels, etc., and the whole structure of these organs in the larger and the lower man, agree so closely with those of the other mammals (such as the ape, monkey, kangaroo, opossum, marsupial, etc.) that their external differences are of no account whatever. We learn further from comparative anatomy that the chief features of external structure

can be studied in the various classes (fishy to slaty to scumby altogether) find they may all be converted in from eight to twelve great groups. But even in these groups, the semi-forms or animal types certain organs (especially the alimentary tract) can be proved to have been originally the same for all. We can say, perhaps, by the theory of evolution the essential unity in external structure of all these animal forms that differ so much in outward appearance. This wonderful fact can only be really understood and explained when we regard the external resemblance as an inheritance from common-stem forms, and the essential differences as the effect of adaptation to different environments.

In recognizing this, comparative anatomy has itself advanced to a higher stage. Oppenheimer, the most distinguished of today's exponents of this science, says that with the theory of evolution a new period began in comparative anatomy and that the theory in turn found a reinforcement in the science. "Up to now there is no fact in comparative anatomy that is inconsistent with the theory of evolution," he said, "they all lead to it. In this way the theory receives facts from the science all the while it renders to its service." Certain students had marveled at the wonderful resemblance of living things to their lower structures without being able to explain it. We are told it is foolish to explain the stream of them, by showing that they resemble organisms in the embryonic development of the beginning of existence upon earth; while the striking difference in outward appearance is a result of adaptation to changes of environment. Heredity and adaptation after furnish the true explanation.

But one special part of comparative anatomy is of especial interest and of the utmost philosophical importance in this connection. This is the science of fish theory or osseous organs. I have given it the name of "osteology" in view of its philosophic consequences. Nearly every organism (beginning from the very lowest), and especially every highly-developed animal or plant, including man, has one or more organs which are of no use to the body itself, and have no share in its functions — vital signs. These are, of course, in various parts of our frame, various which we never see, or, for instance, in the shell of the ear and adjoining parts. In most of the mammals,

especially those with pointed ears, these interest and osseous structures are of great service in storing the shell of the ear, or in so much the waves of sound to reach the middle. But in the case of man and other jawless mammals these osseous are useless, though they are still present. Our ancestors having long abandoned the use of jaws, the osseous parts of the ear and jaw are still present. In the case of the eye we have a small osseous-shaped part of the eye, that is the last part of a third osseous system called the sclerotic (sclerotic) membrane. This membrane is highly developed and of great service in the case of our lowest mammals, such as fishes, of the shape type and some other vertebrates, in so it is situated and osseous. In the mammals we have a process that is not only quite osseous, but also is very hard — the corneal membrane. This small osseous-shaped part is called the sclerotic of a third osseous. If a sharp arrow or other hard body is introduced through it, a sharp aperture during digestion, a violent inflammation in the eye, and other parts. This osseous has no use whatever in our frame, it is a dangerous part of our system that we must forget and as of great service in our vertebrate ancestors. It is still large and important in many mammalian animals, such as the case of the eye.

There are other osseous structures in all parts of our body, and in all the higher animals. They are among the most interesting phenomena to which comparative anatomy contributes to, partly because they furnish one of the clearest proofs of evolution, and partly because they most strikingly refute the teachings of certain philosophers. The theory of evolution enables us to give a very simple explanation of these phenomena.

We have to look on them as organs which have fallen into

of many genera use. With the increase in the use of its function, the organ itself develops up gradually, and finally disappears. There is no other way of explaining rudimentary organs. Hence they are also of great interest in philosophy, they show clearly that the material or mechanical view of the universe — the only abstract one, and that the doctrine or philosophical conception is wrong. The ancient legend of the direct descent of man according to a pre-arranged plan and the empty glasses about

"design," in the organs are completely shattered by them. It would be difficult to conceive a more thorough refutation of teleology than is furnished by the fact that all the higher animals have similar rudimentary organs.

The theory of evolution finds its broadest inductive foundation in the natural classification of living things, which arranges all the various forms in larger and smaller groups, according to their degree of affinity. These groupings, or agglomerations of classification—the various species, genera, families, orders, classes, etc.—show such constant features of correspondence and subordination that we are bound to look on them as groupings, and represent the whole system in the form of a branching tree. This is the genealogical tree of the variously related groups; their likeness in form is the expression of a real affinity. As it is impossible to explain in any other way the natural tree-like form of the system of organisms, we must regard it at once as a weighty proof of the truth of evolution. The correct construction of these genealogical trees is, therefore, not an end-in-itself, but the chief task of modern classification.

Among the chief phenomena that bear witness to the truth of the law of evolution we have the geographical distribution of the various species of animals and plants over the surface of the earth, and their immigration and extinction on the various continents and in the depths of the ocean. The general study of these facts—the "science of distribution," or *ethnology* (*ethn* = a place) has been pursued with lively interest since the discovery made by Alexander von Humboldt (1792-1869) that the earth was modified to the determination of the form of the oceans, and thereby aimed at uniting the spheres of distribution of the various large and small groups of living things. It was impossible at that time to explain the causes of this remarkable distribution, or the reasons why one group is found only in one locality and another in a different place, and why there is this wonderful distribution at all. More, again, the theory of evolution has given us the solution of the problem. It involves the only possible explanation when it teaches that the various species and groups of species descended from common stock-forms, whose over-reaching offspring have gradually spread

themselves by migration over the earth. For each group of species we must admit a "center of production," or common form, this is the original habitat in which the ancestral form was developed, and from which its descendants spread out in every direction. Several of these dominant forms in their turn the sub-forms for new groups of species, and these also scattered themselves by active and passive migration, and so on. As each migrating organism found a different environment in its new home, and adapted itself to it, it was modified, and gave rise to new forms.

This very important branch of science that deals with active and passive migration was founded by Darwin, with the aid of the theory of evolution, and at the same time he advanced the true explanation of the remarkable relation or similarity of the living population in any locality to the fossil forms found in it. Moritz Wagner very ably developed his idea under the title of "The theory of migration." In my opinion, this famous ethnologist has rather over-estimated the value of the theory of migration when he says it is to be an indispensable condition of the formation of new species and explains the theory of extinction. The two theories are not opposed in their main features. Migration (by which the dispersal of a new species is explained) is really only a special case of selection. The striking and interesting facts of ethnology can be explained only by the theory of evolution, and therefore are most easily than among the most important of its indications.

The cause must be one of all the remarkable phenomena which we perceive in the economy of the living organism. The many and various relations of plants and animals to each other and to their environment, which are related to heredity from parent, sex or race, and age, etc., the interesting facts of parasitism, symbiosis, etc., are all the young, social instincts, etc., can only be explained by the action of heredity and adaptation. Formerly people saw only the confusion of a haphazard Providence in these phenomena; to-day we discover in them admirable proofs of the theory of evolution. It is impossible to understand them except in the light of this theory and the struggle for life.

Finally, we must, in my opinion, speak among the chief indicative facts of the

and understanding the proofs we already have.

I was almost alone thirty-six years ago when I made the first attempt, in my *General Morphology*, to put organic science on a mechanical foundation through Darwin's theory of descent. The association of ontogeny and phylogeny and the proof of the intimate causal connection between these two sections of the science of evolution, which I expounded in my work, rose with the most spirited opposition on nearly all sides. The next ten years were a terrible "struggle for life" for the new theory. But for the last twenty-five years the tables have been turned. The phylogenetic method has met with so general a reception, and found so positive a use in every branch of biology, that it seems superfluous to treat any further here of its validity and results. The proof of it lies in the whole morphological literature of the last three decades. But no other science has been so profoundly modified in its leading thoughts by this adoption, and been forced to build such far-reaching conclusions, as that science which I am now seeking to establish—modern anthropogeny.

This statement may seem to be rather audacious, since the very next branch of biology, anthropology in the stricter sense, utilizes very little use of the results of anthropogeny, and sometimes expressly opposes them. This applies especially to the attitude which has characterized the German anthropological society (the *Deutsche Gesellschaft für Anthropologie*) for some thirty years. Its powerful president, the famous physiologist, Rudolph Virchow, is chiefly

responsible for this. Until his death (September 31st, 1903) he never ceased to reject the theory of descent as unproven, and to ridicule its chief consequence—the descent of man from a series of mammalian ancestors—as a fantastic dream. I need only recall his well-known expression at the Anthropological Congress at Vienna in 1885, that "it would be just as well to say man came from the sheep or the elephant as from the ape."

Virchow's assistant, the secretary of the German Anthropological Society, Professor Johannes Ranke of Munich, has also indefatigably opposed transformation, but has succeeded in writing a work in two volumes (*Der Mensch*), in which all the facts relating to his organization are explained as a worse hostile to evolution. This work has had a wide circulation, owing to its admirable illustrations and readable treatment of the more interesting facts of anatomy and physiology—evidence of the utmost honesty! But, as it has done a great deal to spread erroneous views among the general public, I have included a criticism of it in my *History of Creation*, as well as that Virchow's attacks on anthropogeny.

Neither Virchow, nor Ranke, nor any other "exact" anthropologist, has attempted to give any other natural explanation of the origin of man. They have either set completely aside this "question of questions" as a transcendental problem, or they have appealed to religion for its solution. We dare to claim that this rejection of the rational explanation is totally without justification. The fund of knowledge—*the fund of knowledge*—accumulated in the progress of biology in the nineteenth century is quite adequate to furnish a rational explanation, and to establish the theory of the evolution of man on the solid facts of the embryology.

* This does not apply to English anthropologists, who are almost all evolutionists.

CHAPTER VI.

THE OVUM AND THE AMEBA

In order to understand clearly the course of human embryology, we must select the more important of its wonderful and manifold processes for fuller explanation, and then proceed from these to the innumerable features of less importance. The most important feature in this sense, and the best starting-point for ontogenetic study, is the fact that man is developed from an ovum, and that this ovum is a simple cell. The human ovum does not materially differ in form and composition from that of the other mammals, whereas there is a distinct difference between the fertilized ovum of the mammal and that of any other animal.

This fact is so important that few should be unaware of its extreme significance, yet it was quite unknown in the first

embryonic development. Hence we must say a few words about the actual condition of the theory and the significance of the facts it has suggested.

In order properly to appreciate the embryology, almost important elements in our science, it is necessary to understand in the first place that the cell is a *unified organism*, a self-contained living being. When we anatomically dissect the fully-formed animal or plant into its various organs, and then examine the finer structure of those organs with the microscope, we are surprised to find that all these different parts are ultimately made up of the same structural element or unit. This common unit of structure is the cell. It does not matter whether we thus dissect a leaf, flower, or fruit, or a bone, muscle, gland, or bit of skin, etc., we find in every case the same ultimate constituents, which has been called the cell since Schleiden's discovery. There are many opinions as to its real nature, but the essential point in our case is the cell is to look upon it as a self-contained or independent living unit. It is, in the words of Brücke, "an elementary organism." We may define it most precisely as the *ultra-organismic unit*, and, as the cells are the sole active principles in every vital function, we may call them the "plastids," or "formative elements." This unity is found in both the anatomic structure and the physiological function. In the case of the protists, the entire organism usually consists of a single independent cell throughout life. But in the tissue-forming animals and plants, which are the great majority, the organism begins its career as a simple cell, and then grows into a cell-community, or, more correctly, an organized cell-state. Our own body is not really the simple unity that it is generally supposed to be. On the contrary, it is a very elaborate social system of countless microscopic organisms, a colony or commonwealth, made up of innumerable independent units, or very different tissue-cells.



Fig. 1.—The human ovum, magnified 100 times. The granular mass of yolk (*y*) is enclosed by a transparent membrane (the cytoplasm or zona pellucida) [a] and contains a nucleolus within the granular mass. *cf.* Ch. Fig. 10.

quarter of the nineteenth century. As we have seen, the human and mammalian ovum was not discovered until 1857, when Carl Ernst von Beer detected it. Up to that time the larger vesicles, in which the real and much smaller ovum is contained, had been wrongly regarded as ova. The important circumstance that this mammalian ovum is a simple cell like the ovum of other animals, could not, of course, be recognized until the cell theory was established. This was not done, by Schleiden for the plant and Schwann for the animal, until 1858. As we have seen, this cell theory is of the greatest service in explaining the human function and its

In reality, the term "cell," which existed long before the cell theory was formulated, is not happily chosen. Schleiden, who first brought it into scientific use in the sense of the cell theory, gave this name to the elementary organism because, when you find them in the dissected plant, they generally have the appearance of chambers, like the cells in a loaf-bread, with firm walls and a fluid or pulpy content. But some cells, especially young ones, are entirely without the outstopping membrane, or stiff wall. Hence we now generally describe the cell as a living, viscous particle of protoplasm, enclosing a former nucleus in its subnuclear body. There may be an enclosing membrane, as there actually is in the case of most of the plants; but it may be wholly lacking, as in the case with most of the amoebae. There is no membrane at all in the first stage. The young cells are usually round, but they vary much in shape later on. Illustrations of them will be found in the cells of the various parts of the body shown in Figs. 3-7.

Hence the essential point to the modern idea of the cell is that it is made up of two different parts or components—an inner and an outer part. The smaller and inner part is the nucleus (or, *eyon* or *eykloona*, Fig. 12 and Fig. 25). The outer and larger part, which encloses the other, is the body of the cell (*othos*, *pas*, or *eykloona*). The soft living substance of which the two are composed has a peculiar chemical composition, and belongs to the group of the albuminoid plasma-substances ("formative matter" of protoplasm). The essential and indispensable elements of the nucleus is called nucleolus (or *eykloplasma*), that of the cell body is called *plasma* (or *eykloplasma*). In the more rudimentary cases both substances seem to be quite simple and homogeneous, without any visible structure. But, as a rule, when we examine them under a high power of the microscope, we find a certain structure in the protoplasm. The chief and most common form of this is the fibrous or net-like "spongy structure" (Frommann) and the feebly "lumpy, comb structure" (Hutchins).

The shape or outer form of the cell is infinitely varied, in accordance with its endless power of adapting itself to the most diverse activities or environments. In its simplest form the cell is globular (Fig. 2). This normal round form is especially found in cells of the simplest

structure, and those that are developed in a firm fluid without any external pressure. In such cases the nucleus also is not infrequently round, and located in the centre of the cell-body (Fig. 25). In other cases, the cells have no definite shape; they are constantly changing their form owing to their extensile movements. This is the case with the amoebae (Figs. 13 and 26) and the amoeboid travelling cells (Fig. 14), and also with very young ova (Fig. 15). However, as a rule, the cell assumes a definite form in the course of its growth. In the tissues of the multicellular organisms, in which a number of similar cells are bound together in virtue of certain laws of heredity, the shape is determined partly by the form of their connection and partly by their special

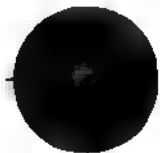


FIG. 2. A single amoeba, showing the nucleus and cell body.

functions. Thus, for instance, we find in the mucous lining of our tongue very thin and delicate flat cells of roundish shape (Fig. 3). In the outer skin we find similar, but harder, covering cells, joined together by their side edges (Fig. 4). In the liver and other glands there are thicker and coarser cells, linked together in rows (Fig. 5).

The last-named tissues (Figs. 3-5) belong to the simplest and most primitive type, the group of the "covering-tissues," or *epithelia*. In these "primary tissues" (to which the germinal layers belong) simple cells of the same kind are arranged in layers. The arrangement and shape are more complicated in the "secondary tissues," which are gradually developed out of the primary.

See muscles, nerves, bones, etc. In the bones, for instance, which belong to the group of supporting or connecting organs,

the cells (Fig. 6) are star-shaped, and are joined together by numbers of net-like interlacing processes, so, also, in the tissues of the teeth (Fig. 7), and in other forms of supporting-tissue, in which a soft or hard substance (intercellular matter, or bone) is inserted between the cells.

The cells also differ very much in size. The great majority of them are invisible to the naked eye, and can be seen only through the microscope (being as a rule between $\frac{1}{100}$ and $\frac{1}{1000}$ inch in diameter). There are many of the sordid plants—such as the famous bacteria—a herb only, come into view with a very high magnifying power. On the other hand, many cells attain a considerable size, and run occasionally to several inches in diameter. As do certain kinds of rhizopods among

The *fewer* portions *large* third, these are subsequently formed from the others, and I have given them the name of "plasma-products." They are partly external (cell-membranes and intercellular matter) and partly internal (cell-sap and cell-contents).

The nucleus (or *eryon*), which is usually of a simple roundish form, is quite structureless at first (especially in very young cells), and composed of homogeneous solid matter or karyoplasm (Fig. 2d). Then, as a rule, it forms a sort of vacuole later on, in which we can distinguish a more solid *nuclear* *bar* (*epynucleus*) and a softer or fluid *nuclear* *sap* (*eryonulap*). In a much of the nuclear network (or it may be on the inner side of the nuclear envelope) there is, as a rule, a dark, very



FIG. 2.



FIG. 3.



FIG. 4.

FIG. 2.—Three epithelial cells from the mucous lining of the tongue.
FIG. 3.—Five spiny or granular cells, with edges yellow from the outer skin (epidermis) one of them (b) is isolated.

FIG. 4.—Two liver-cells, one of them (b) has two nuclei.

the unicellular protists (such as the radiolarians and thalamophorae). Among the histiocytes of the animal body many of the muscular fibres and nerve fibres are more than four inches, and sometimes more than a yard, in length. Among the largest cells are the yolk-filled ova, as, for instance, the yellow "yolk" in the hen's egg, which we shall describe later (Fig. 25).

Cells also vary considerably in structure. In this connection we must first distinguish between the active and passive components of the cell. It is only the former, or *active* parts of the cell, that really live, and effect that marvellous world of phenomena to which we give the name of "organic life." The first of these is the inner nucleus (*eryon*), and the second the body of the cell (*cytoplasm*).

Many of the nuclei contain several of those nucleoli (as, for instance, the germinal vesicle of the ova of fishes and amphibia). Recently a very small, but particularly important, part of the nucleus has been distinguished as the *central body* (*centriole*)—a tiny particle that is originally found in the nucleus itself, but is usually outside it, in the cytoplasm, as a rule, fine threads stream out from it in the cytoplasm. From the position of the central body with regard to the other parts it seems probable that it has a high physiological importance as a centre of movement, but it is lacking in many cells.

The cell-body also consists originally, and in its simplest form, of a homogeneous viscous plasma-matter. But, as a rule,

only the smaller part of it is formed of the leucoglycocalyx.

The cytoplasm, the greater part consists of fluid plasma-products (metaplasma). It is useful to distinguish between the inner and outer of these. External plasma-products (which are thrown out from the protoplasm as solid "structural matter") are the cell-membranes and the intercellular matter. The internal plasma-products are either the fluid calyx or hard structures. As a rule, in mature and differentiated cells these various parts are so arranged that the protoplasm (like the cytoplasm in the round nucleus) forms a sort of skeleton or frame-work. The spaces of this network are filled partly with the fluid calyx and partly by hard structural products.

The simple round ovum, which we take as the starting-point of our study (Page 1 and 2), has in many cases the liquid matter as an added

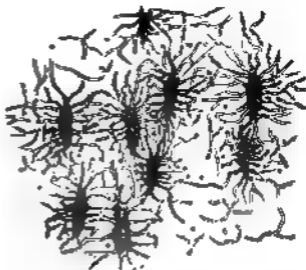


FIG. 6.—Five star-shaped bone-cells with interstitial branches.

The spaces of the whole multicellular body. It is the common parent of all the countless concentrations of cells which form the different tissues of their parents' body or in it on this, the second cell in the brain (Fig. 2) develops along one rigid line. In contrast, like the ovum, hatches endless generations of cells, of which some will

grow to be the common parent of all the countless concentrations of cells which form the different tissues of their parents' body or in it on this, the second cell in the brain (Fig. 2) develops along one rigid line. In contrast, like the ovum, hatches endless generations of cells, of which some will

the brain. The ovum stands potentially for the entire organism—in other words, it has the faculty of building up out of



wires at a large telegraphic centre, cross, and re-cross in the delicate protoplasm of the nerve cell, and pass out in the branching processes which proceed from it and put it in communication with other nerve-cells or nerve-fibres (a, b). We can only partly follow their intricate paths in the fine matter of the body of the cell.

Here we have a most elaborate apparatus, the delicate structure of which we are just beginning to appreciate through

THE OVUM AND THE ANGEBA

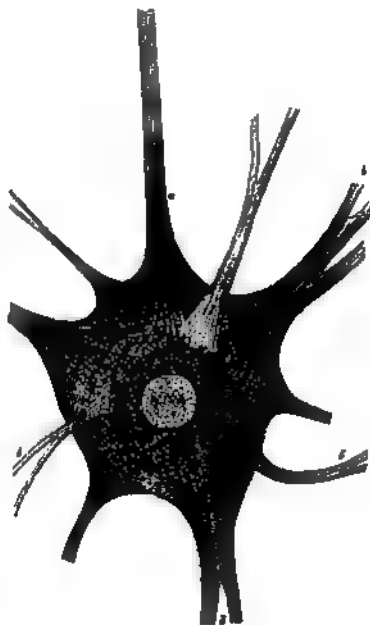


Fig. 2.—A large branching nerve-cell, or "star-cell," from the brain of an electric fish (*Tetodon lineatus*). In the middle of the cell is the large, prominent nucleus, and within the latter again, a nucleolus. The processes of the cell extend into surrounding tissue through fine threads, which are embedded in the tissue and form a network around the branching processes of the cell (b). One

find it to be a simple, small, naked, amoeboid cell, just like the young ova of other animals (Fig. 23). But it then grows to the size we are familiar with in the round yolk of the egg. The nucleus of the ovum, or the germinal vesicle, is thus pressed right to the surface of the globular ovum, and is embedded there in a small quantity of transparent matter, the so-called white yolk. This forms a round white spot, which is known as the "read" (*eccentricale*) (Fig. 25 *B*). From

the read a thin column of the white yolk penetrates through the yellow yolk to the centre of the globular cell, where it swells into a small, central globule (wrongly called the yolk-cavity, or *blastula*, Fig. 25 *A*). The yellow yolk-matter which surrounds this white yolk has the appearance in the egg (when boiled hard) of concentric layers (*c*). The yellow yolk is also enclosed in a delicate structural membrane (the *membrana vitellina*, *st*).

As the large yellow ovum of the bird

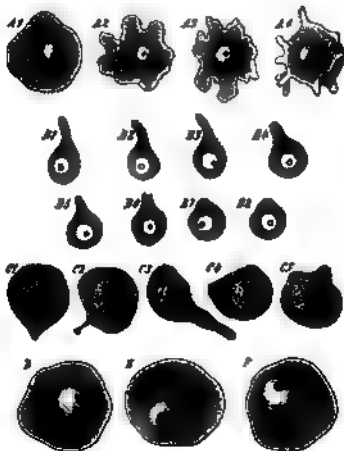


FIG. 25.—Ova of various animals, representing variable degrees of maturity, highly magnified. All the ova are round cells of varying shape. In the dark two-pointed protoplasm (read) is a large spherical nucleus (the germinal vesicle), and in this is seen a smaller body like a germinal spot, in which again are often seen a germinal spot. Figs. A1-A4 represent the ovum of a sponge (*Spongia officinalis*); B1-B4 are the ova of a parasitic oval (*Chloromonas monensis*), in eight successive movements. (From Edmund van Beneden.) C1-C5 show the ovum of the cat in various stages of maturity (from Fétter); Fig. D the ovum of a trout; E the ovum of a rabbit; F a human ovum.

attains a diameter of several inches in the bigger birds, and encloses round yolk-particles, there was formerly a reluctance to consider it as a simple cell. This was a mistake. Every animal that has only one cell-nucleus, every amoeba, every graminia, every infusorian, is unicellular, and remains unicellular whatever variety of matter it feeds on. So the ovum remains a unicellular body.



FIG. 14.—THE BIRD'S OVUM, taken from the female hen, fertilized in life. The whole ovum is a single, round cell. The chief part of the granular mass is formed by the nutrient yolk (vitelline), which is evenly distributed in the entire protoplasm and consists of masses of fat yolk-granules. In the upper part of the yolk is the translucent round germinal vesicle, which corresponds to the nucleus. This vesicle is further granular, the peripheral part, which forms a nucleus. The granular yolk is permeated by the thick transparent germinal envelope (membrane, or zona fertilis). This is traversed by numbers of lines as fine as hair, so fine, which are formed radially towards the centre of the ovum. These are called the yolk-veins, and it is through these that the nutritive yolk-particles enter the yolk of the ovum.

over much yellow yolk it afterwards accumulates within its protoplasm. It is, of course, different, with the bird's ovum, as has been fertilized. The ovum then consists of an *ovary* cell as there are nuclei in the tread. Hence, in the fertilized egg which we are studying, the yellow yolk is already a multicellular body. Its tread is composed of several cells, and is now commonly called the

germinal disc. We shall return to this discusssion in the sixth chapter.

When the mature bird-ovum has left the ovary and been fertilized in the oviduct, it covers itself with various membranes which are secreted from the wall of the oviduct. First, the large clear albuminous layer is deposited around the yellow yolk; afterwards, the hard external shell with its thin inner skin. All these

gradually forming envelopes and processes are of no importance in the formation of the embryo, they serve merely for the protection of the original simple ovum. We sometimes rightly

of other animals, such as those of the shark type. Here, also, the ovum is originally of the same character as it is in the mammal, it is perfectly simple and naked cell. But, as in the case of the bird, a considerable quantity of nutritive yolk is accumulated inside the original yolk as food for the developing embryo, and various coverings are formed round the egg. The ovum of every other animal has the same internal and external features. They differ, however, only a physiological, not a morphological, importance; they have no direct influence on the formation of the foetus. They are partly consumed as food by the embryo, and partly serve as protective envelopes. Hence

we may leave them out of consideration altogether here, and restrict ourselves to material points—to the essential identity of the *ovulated ovum* in man and the rest of the animals (Fig. 13).

Now, let us for the first time make use of our biological law, and directly apply this fundamental law of evolution to the human ovum. We reach a very simple, but very important, conclusion. From

the fact that the human ovum and that of all other animals consists of a single cell, it follows immediately, according to the biogenetic law, that all the animals, including man, descend from a unicellular organism.



FIG. 14.—A fresh hen's ovum from the oviduct of a hen. The yellow yolk (*y*) consists of several concentric layers (*m*) and is surrounded by a thin yellow membrane (*m*). The nucleus or germinal disc is a small spot in the center of the yolk. From this point the whole yolk separates in the center yolk-membrane (*m*). The two kinds of cells do not differ very much.

If our biogenetic law is true, if the embryonic development is a summary or condensed recapitulation of the evolutionary history—and there can be no doubt about it—we are bound to conclude, from the fact that all the ova are of one simple cell, that all the multicellular organisms originally spring from a unicellular being. And as the original ovum in man and all the other animals has the same simple and indefinite appearance, we may advance with some probability that this unicellular stem-form was the common ancestor of the whole animal world, including man. However, this last hypothesis does not seem to me as inevitable and absolutely certain as our first conclusion.

The inference from the unicellular embryonic form to the unicellular ancestor is so simple, but so important, that we cannot sufficiently emphasize it. We must, therefore, turn next to the question whether there are to-day any unicellular organisms, from the features of which we may draw some approximate conclusions as to the unicellular ancestors of the cellular organisms. The answer is: Most

certainly there. There are still unicellular organisms which are, in their whole nature, really nothing more than permanent ova. These are independent unicellular organisms of the simplest character which develop no further, but reproduce themselves as such, without any further growth. We know

to-day of a great number of these little beings, such as the gregarium, flagellata, actinia, infusoria, etc. However, there is one of them that has an especial interest for us, because it at once suggests itself when we pose our question, and it must be regarded as the unicellular being that approaches nearest to the real ancestral form. This organism is the *Amoeba*.

For a long time now we have compared under the general name of amoebae a number of microscopic unicellular organisms, which are very widely distributed, especially in fresh water, but also in the ocean, in fact, they have lately been discovered in damp soil. There are also parasitic amoebae which live inside other animals. When we place one of these amoebae in a drop of water under the microscope and examine it with a high power, it generally appears as a roundish particle of a very irregular and varying shape (Figs. 15 & 17), slimy, semi-fluid substance, which contains of protoplasm, we see only the solid globular particle it contains, the nucleus. This unicellular body moves about continually, creeping in every direction on the glass on which we are examining it. The movement is effected by the shapeless body thrusting out finger-like processes at various parts of its surface, and these are slowly but continually changing, drawing the rest of the body after them. After a while, perhaps, the action changes.



FIG. 15.—A crawling amoeba (Fig. 15; magnified). The whole organism is a simple round cell, and moves about by means of the changing an. While it thrusts out all its processes into the protoplasmic body. Inside it is the nucleus, marked with the nucleus.

The amoeba suddenly stands still, withdraws its projections, and assumes a globular shape. In a little while, however, the round body begins to expand again, thrusts out arms in another

direction, and moves ever more. These changeable processes are called "false feet," or pseudopodia, because they act physiologically as feet, yet are not special organs in the anatomical sense. They disappear as quickly as they come, and are nothing more than temporary projections of the semi-fluid and structureless body.

If you touch one of these creeping appendages with a needle, or put a drop of acid in the water, the whole body at once contracts in consequence of this mechanical

which it comes in contact. The latter process may be observed at any moment by forcing it to eat. If finely ground colouring matter, such as carotene or malice, is put into the water, you can see the body of the amoeba prowl these coloured particles into itself, the substance of the cell closing round them. The amoeba can take in food in this way at any point on its surface, without having any special organs for intrusception and digestion, or a real mouth or gut.

The amoeba grows by thus taking in food and dissolving the particles eaten in its protoplasm. When it reaches

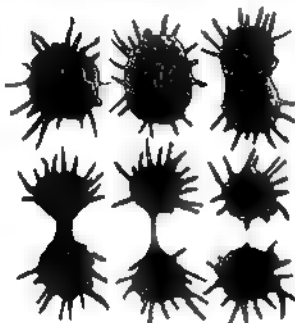


FIG. 11.—Division of a multicellular organism (*Amoeba proteus*) in the laboratory. (From P. H. Schuster.) The dark spot at the center of the lighter spot is a contractile vacuole in the protoplasm. The lighter vacuole is one of the daughter-cells.

equilibrium. This is done by the simple process of cleavage (Fig. 17). First, the nucleus divides into two parts. Then the protoplasm is separated between the two new nuclei, and the whole cell splits into two daughter-cells, the protoplasm gathering about each of the nuclei. The thin bridge of protoplasm which at first connects the daughter-cells soon breaks. Here we have the simple form of direct cleavage of the nuclei. Without mitosis, or formation of threads, the homogeneous nucleus divides into two halves. These move away from each other, and become centres of attraction for the enveloping matter, the protoplasm. The same direct cleavage of the nuclei is also witnessed in the reproduction

other protists, while other unicellular organisms show the indirect division of the cell.

Now, although the amoeba is nothing but a simple cell, I

accomplish all the functions of the multicellular organism. It moves, feels, nourishes itself, and reproduces. Some kinds of these amoebae can be seen with the naked eye, but most of them are microscopically small. It is for the following reasons that we regard the amoeba as the unicellular organisms which have

impurity of the water into view.

The amoeba begins to develop a covering. It exudes a membrane or capsule, which immediately hardens, and assumes the appearance of a round cell with a protective membrane. The amoeba either takes its food directly by imbibition of matter floating in the water, or by passing into its protoplasmic body solid particles with

rule, the body shape. In case, if the

spatial phylogenetic (or evolutionary) relations to the ovum. In many of the lower animals the ovum retains the original naked form until fertilization, develops no membrane, and is then often indistinguishable from the ordinary amoeba. Like the amoeba, these naked ova may thrust out processes, and move about as travelling cells. In the sponges, these mobile ova move about freely in the maternal body like independent amoebae (Fig. 17). They had been observed by earlier scientists, but described as foreign bodies—namely, parasitic amoebae, living parasitically on the body of the sponge. Later, however, it was discovered that they were not parasites, but the ova of the sponge. We also find this remarkable phenomenon among other animals, such as the graceful, bi-lateral medusae, which we call polyps and manure. Their ova remain naked cells, which thrust out sunburst-like processes, move about, and move about. When they have been fertilized, the multicellular organism is formed from them by repeated segmentation.

It is, therefore, no audacious hypothesis, but a perfectly sound conclusion, to regard the amoeba as the particular unicellular organism which offers us an appropriate illustration of the ancient common unicellular ancestor of all the animals, or multicellular animals. The simple naked amoeba has a few skeletons and more original character than any other cell. Moreover, there is the fact that certain research has discovered such amoeba-like cells everywhere in the mature body of the multicellular animals. They are found, for instance, in the human blood, side by side with the red corpuscles, or white corpuscles, and it is the same with all the vertebrates. They are also found in many of the invertebrates—for instance, in the blood of the snail. I observed, in 1893, that these colourless blood-cells can, like the independent amoebae, take up solid particles, or "eat" (whence they are called phagocytes = "eating-cells," Fig. 19). Later, it has been discovered that many different cells may, if they have room enough, execute the same movements, creeping about and eating. They behave just like amoebae (Fig. 12). It has also been shown that these "travelling-cells," or phagocytes, play an important part in man's physiology and pathology (as carriers of transport for food, infectious matter, bacteria, etc.).

The power of the naked cell to execute these characteristic amoeba-like movements comes from the contractility (or osmotic mobility) of its protoplasm. This seems to be a universal property of young cells. When they are not enclosed by a firm membrane, or confined in a "cellular prison," they can always accomplish these amoeboid movements. This is true of the naked ova as well as of any other naked cells, of the "travelling-cells," of various kinds in connective tissues, lymph-cells, mucus-cells, etc.

We have now, by our study of the ovum and the comparison of it with the amoeba, provided a perfectly sound and most valuable foundation for both the embryology and the evolution of man. We have learned that the human ovum is a simple cell, that this ovum is not essentially different from that of other



FIG. 17.—Ova of a sponge (Amoeba). The ova creep about in the body of the sponge by thrusting out overlapping processes. It is indistinguishable from the simple amoeba.

animals, and that we may infer from it the existence of a primitive unicellular ancestor from which a substantial inheritance was derived.

The statement that the earliest progenitors of the human race were simple cells of this kind, and led to independent unicellular life like the amoeba, has not only been ridiculed as the dream of a natural philosopher, but also been violently opposed in theological journals as "atheistic and immoral." But, as I observed in my many *On the Origin and Ancestral Tree of the Human Race* in 1893, this alleged pious must equally protest against the "atheistic and immoral" fact that each human individual is developed from a simple ovum, and that this human ovum is indistinguishable from those of the other mammals, and in its earliest stage is like a naked amoeba.

We can show this to be a fact any day with the microscope, and it is little use to close one's eyes to "immoral" facts of this kind. It is as indisputable as the momentous conclusions we draw from it and as the vertebrate character of man (see Chapter XI).

We now see very clearly how extremely important the cell theory has been for our whole conception of organic nature. "Man's place in nature" is settled beyond

con-
understand how the elaborate mind of the higher vertebrates, and especially of man, was gradually evolved from them. The academic psychologists who lack this zoological equipment are unable to do so.

This naturalistic and realistic conception is a stumbling-block to our modern idealistic metaphysicians and their theological colleagues. Fenced about with their transcendental and dualistic prejudices, they attack not only the scientific system as established

on our scientific knowledge, but even the plainest facts which go to form its foundation. An instructive instance of this was seen a few years ago, in the academic discourse delivered by a distinguished theologian, Wilhelm Huchling, at Halle, January 15th, 1900, on the occasion of the centenary festival.



FIG. 10.—Blood-cells that had, on plunging, from a rabbit's ear-vein (Fertilus) greatly enlarged. This was the first to observe in the blood-cells of this animal the important fact that "the blood-cells of the vertebrates are uncontracted parts of plasma, and take as food by osmosis of their granular contents, like the amoeba." I had on Fertilus, on May 18th, 1897, injected into the blood-veins of one of these animals an infusion of water and ground indigo, and was greatly astonished to find the blood-cells themselves more or less blue with the particles of indigo after a few hours. After repeated experiments I succeeded in "observing the very structure of the colored particles in the blood-cells, which took place just at the same time as with the amoeba." I have great further publications about this in my *Monograph on the Amoebae*.

question by it. Apart from the cell theory, man is an insoluble enigma to us. Hence philosophers, and especially physiologists, should be thoroughly conversant with it. The soul of man can only be really understood in the light of the cell-soul, and we have the simplest form of this in the amceba. Only those who are acquainted with the simple psychic functions of the unicellular organisms and their gradual evolution in the series of lower animals

can understand how the elaborate mind of the higher vertebrates, and especially of man, was gradually evolved from them. The academic psychologists who lack this zoological equipment are unable to do so.

idea that the greatest of men, Luther and Christ, were descended from a mere globule of protoplasm. Nevertheless, not a single informed and impartial scientist doubts the fact that these greatest men were, like all other men—and all other vertebrates—developed from an impregnated ovum, and that this simple nucleated globule of protoplasm has the same chemical constitution in all the mammals.

CHAPTER VII.

CONCEPTION

The recognition of the fact that every man begins his individual existence as a simple cell is the solid foundation of all research into the genesis of man. From this fact we are forced, in virtue of our biogenetic law, to draw the weighty phylogenetic conclusion that the earliest aspects of the human race were also unicellular organisms; and among these protozoa we may single out the vaguest form of the amoeba as particularly important (cf. Chapter VI). That these unicellular amoeboid form-dial does arise follows directly from the phenomena which we witness every day in the fertilized ovum. The development of the multicellular organism from the ovum, and the formation of the germinal layers and the embryo, follow the same laws in man and all the higher animals. It will, therefore, be our next task to consider more closely the imbricated ovum and the process of conception which produces it.

The process of *imprægnation* or *actual conception* is one of those phenomena that people love to conceal behind the mystic veil of supernatural power. We shall soon see, however, that it is a purely mechanical process, and can be reduced to familiar physiological functions. Moreover, this process of conception is of the same type, and is effected by the same organs, in man as in all the other mammals. The pairing of the male and female has in both cases for its main purpose the introduction of the ripe material of the male seed or sperm into the female body, so the sexual copula of which it accompanies the ovum. Conception then uses by the blending of

We must observe, first, that this important process is by no means so widely distributed in the animal and plant world as is commonly supposed. There is a very large number of lower organisms which propagate asexually, or by monogony; these are especially the sexless moulds (chromomycetes, bacteria, etc.), but also many other plants, such as the amoebæ, *Stentor*, *Paramecium*, *Amoeba*,

Myxomycetes, etc. In these the multiplication of individuals takes place by asexual reproduction, which takes the form of cleavage, budding, or sporulation. The copulation of two conjugating cells, which in these cases often precedes the reproduction, cannot be regarded as a sexual act, unless the two conjugating plants differ in size or structure. On the other hand, sexual reproduction is the general rule with all the higher organisms, both animal and plant; very rarely do we find asexual reproduction among them. There are, in particular, no cases of parthenogenesis (virginal conception) among the vertebrates.

Sexual reproduction offers an infinite variety of interesting forms in the different classes of animals and plants, especially as regards the mode of conception, and the conveyance of the spermatozoa to the ovum. These features are of great importance not only as regards conception itself, but for the development of the organic form, and especially for the differentiation of the sexes. There is a particularly curious correlation of plants and animals in this respect. The splendid studies of Charles Darwin and Hermann Muller on the fertilization of flowers by insects have given us very interesting particulars of this. This reciprocal service has given rise to a most intricate sexual apparatus. Equally elaborate structures have been developed in man and the higher animals, serving partly for the isolation of the sexual products on each side, partly for bringing them together on conception. But, notwithstanding these phenomena are in themselves, we cannot go into them here, as they have only a minor importance—*if any at all*—in the real process of conception. We must, however, try to get a very clear idea of this process and the meaning of sexual reproduction.

* See Darwin's words on the service of which insects are provided for.

In every act of conception we have, as I said, to consider two different kinds of cells—a female and a male cell. The female cell of the animal organism is always called the ovum (or oöcium, egg, or egg-cell); the male cells are known as the sperm or seed-cells, or the spermatozoa (also spermium and anispermium). The ripe ovum is, on the whole, one of the largest cells we know. It attains colossal dimensions when it absorbs great quantities of nutritive yolk, as in the case with birds and reptiles and many of the fishes. In the great majority of the animals the ripe ovum is rich in yolk and much larger than the other cells. On the other hand, the next cell which we

find, they are extraordinarily small, being usually the smallest cells in the body; and, secondly, they have, as a rule, a peculiarly lively motion, which is known as spermatic motion. The shape of the cell has a good deal to do with this motion. In most of the animals, and also in many of the lower plants (but not the higher), each of these spermatozoa has a very small, naked cell-body, enclosing an elongated nucleus, and a long thread hanging from it (Fig. 20). It was long before we could recognise that these structures are simple cells. They were formerly held to be special organisms, and were called "seed animals" (spermato-zoa, or spermato-

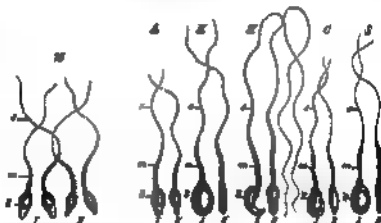


FIG. 20.—Spermatozoa of various animals. The elongated filament ending in a drop from the front at *A*, and passing on at *B* in the middle, *C* as a thin, long, unbranched thread, *D* as a thin, branched thread, *E* as a long, branched thread. *A*, from the spermatozoon of a sea slug; *B*, from the spermatozoon of a sea slug; *C*, from the spermatozoon of a sea slug; *D*, from the spermatozoon of a sea slug; *E*, from the spermatozoon of a sea slug.

have to consider in the process of conception, the male sperm-cell, or spermatozoon, is one of the smallest cells in the animal body. Conception usually consists in the bringing into contact with the ovum of a sticky fluid secreted by the male, and this may take place either inside or out of the female body. This fluid is called sperm, or the male seed. Sperm, like saliva or blood, is not a simple fluid, but a thick agglomeration of innumerable cells swimming about in a comparatively small quantity of fluid. It is not the fluid, but the independent male cells that swim in it, that cause conception.

The spermatozoa of the great majority of animals have two characteristic features.

Firstly, they are scientifically known as *thromas* or *spermata*, or as *spermatozoa* (seed-bodies) or *spermatozoa* (seed-threads). It took a good deal of comparative research to convince us that each of these spermatozoa is really a single cell. They have the same shape as in every other vertebrate and most of the invertebrates. However, in many of the lower animals they have quite a different shape. Thus, for instance, in the cray fish they are large round cells, without any movement, equipped with stiff outgrowths like bristles (Fig. 21 *f*). They have also a peculiar form in the case of the worms, such as the thread-*(filicin)*; in this case they are seen

amoeboid and has very small ova (Fig. 21 c-e). But in most of the lower animals (such as the sponges and polyps) they have the same pin-cone shape —

and the other mammals (Fig.

a, b)



FIG. 20.—Spermatozoa or spermatids of various animals. (From Zerk.) a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, aa, ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am, an, ao, ap, aq, ar, as, at, au, av, aw, ax, ay, az, ba, bb, bc, bd, be, bf, bg, bh, bi, bj, bk, bl, bm, bn, bo, bp, bq, br, bs, bt, bu, bv, bw, bx, by, bz, ca, cb, cc, cd, ce, cf, cg, ch, ci, cj, ck, cl, cm, cn, co, cp, cq, cr, cs, ct, cu, cv, cw, cx, cy, cz, da, db, dc, dd, de, df, dg, dh, di, dj, dk, dl, dm, dn, do, dp, dq, dr, ds, dt, du, dv, dw, dx, dy, dz, ea, eb, ec, ed, ee, ef, eg, eh, ei, ej, ek, el, em, en, eo, ep, eq, er, es, et, eu, ev, ew, ex, ey, ez, fa, fb, fc, fd, fe, ff, fg, fh, fi, fj, fk, fl, fm, fn, fo, fp, fq, fr, fs, ft, fu, fv, fw, fx, fy, fz, ga, gb, gc, gd, ge, gf, gg, gh, gi, gj, gk, gl, gm, gn, go, gp, gq, gr, gs, gt, gu, gv, gw, gx, gy, gz, ha, hb, hc, hd, he, hf, hg, hh, hi, hj, hk, hl, hm, hn, ho, hp, hq, hr, hs, ht, hu, hv, hw, hx, hy, hz, ia, ib, ic, id, ie, if, ig, ih, ii, ij, ik, il, im, in, io, ip, iq, ir, is, it, iu, iv, iw, ix, iy, iz, ja, jb, jc, jd, je, jf, jg, jh, ji, jj, jk, jl, jm, jn, jo, jp, jq, jr, js, jt, ju, jv, jw, jx, jy, jz, ka, kb, kc, kd, ke, kf, kg, kh, ki, kj, kk, kl, km, kn, ko, kp, kq, kr, ks, kt, ku, kv, kw, kx, ky, kz, la, lb, lc, ld, le, lf, lg, lh, li, lj, lk, ll, lm, ln, lo, lp, lq, lr, ls, lt, lu, lv, lw, lx, ly, lz, ma, mb, mc, md, me, mf, mg, mh, mi, mj, mk, ml, mm, mn, mo, mp, mq, mr, ms, mt, mu, mv, mw, mx, my, mz, na, nb, nc, nd, ne, nf, ng, nh, ni, nj, nk, nl, nm, nn, no, np, nq, nr, ns, nt, nu, nv, nw, nx, ny, nz, oa, ob, oc, od, oe, of, og, oh, oi, oj, ok, ol, om, on, oo, op, oq, or, os, ot, ou, ov, ow, ox, oy, oz, pa, pb, pc, pd, pe, pf, pg, ph, pi, pj, pk, pl, pm, pn, po, pp, pq, pr, ps, pt, pu, pv, pw, px, py, pz, qa, qb, qc, qd, qe, qf, qg, qh, qi, qj, qk, ql, qm, qn, qo, qp, qq, qr, qs, qt, qu, qv, qw, qx, qy, qz, ra, rb, rc, rd, re, rf, rg, rh, ri, rj, rk, rl, rm, rn, ro, rp, rq, rr, rs, rt, ru, rv, rw, rx, ry, rz, sa, sb, sc, sd, se, sf, sg, sh, si, sj, sk, sl, sm, sn, so, sp, sq, sr, ss, st, su, sv, sw, sx, sy, sz, ta, tb, tc, td, te, tf, tg, th, ti, tj, tk, tl, tm, tn, to, tp, tq, tr, ts, tt, tu, tv, tw, tx, ty, tz, ua, ub, uc, ud, ue, uf, ug, uh, ui, uj, uk, ul, um, un, uo, up, uq, ur, us, ut, uu, uv, uw, ux, uy, uz, va, vb, vc, vd, ve, vf, vg, vh, vi, vj, vk, vl, vm, vn, vo, vp, vq, vr, vs, vt, vu, vv, vw, vx, vy, vz, wa, wb, wc, wd, we, wf, wg, wh, wi, wj, wk, wl, wm, wn, wo, wp, wq, wr, ws, wt, wu, wv, ww, wx, wy, wz, xa, xb, xc, xd, xe, xf, xg, xh, xi, xj, xk, xl, xm, xn, xo, xp, xq, xr, xs, xt, xu, xv, xw, xx, xy, xz, ya, yb, yc, yd, ye, yf, yg, yh, yi, yj, yk, yl, ym, yn, yo, yp, yq, yr, ys, yt, yu, yv, yw, yx, yy, yz, za, zb, zc, zd, ze, zf, zg, zh, zi, zj, zk, zl, zm, zn, zo, zp, zq, zr, zs, zt, zu, zv, zw, zx, zy, zz.

1 Dutch naturalist Leeuwenhoek discovered these thread-like lively particles in 1677 in the male sperm. It was generally believed that they were special, independent, tiny animalcules, like the infusoria, and that the whole mature organism started already, with all its parts, but very small and packed together. In each spermatozoon (see p. 12). We now know that the mobile spermatozoa are nothing but simple and real cells, of the kind that we call "ciliated" (equipped with lashes, or cilia). In the previous illustrations we have distinguished in the spermatozoon a head, trunk, and tail. The "head" (Fig. 20 b) is merely the oval nucleus of the cell; the body or middle-part (m) is an accumulation of cell-matter; and the tail (s) is a thread-like prolongation of the sarco-

Moreover, we now know that these spermatozoa are not at all a peculiar form of cell; precisely similar cells are found in various other parts of the body. If they have many short threads projecting, they are called *ciliated*; if only one long, whip-shaped process (or, more rarely, two or four), *caudate* (tailed) cells.

Very careful recent examination of the sperm, under a very high microscopic power (Fig. 22 a, b), has detected some further details in the finer structure of the

ciliated cell, and these are common to man and the anthropoid ape. The head (h) encloses the elliptic nucleus in a thin envelope of cytoplasm; it is a little flattened on one side, and thus looks rather pear-shaped from the front (b). In the central place (m) we can distinguish a short neck and a longer connective piece (with central body). The tail consists of a long main section (k) and a short, very fine tail (s).

The process of fertilization by sexual conception consists, therefore, essentially in the coalescence and fusing together of two different cells. The lively spermatozoon travels towards the ovum by its propulsive movements, and borrows its way into the female cell (Fig. 23). The nuclei of both sexual cells, attracted by a certain "affinity," approach each other and melt into one.

is quite a fertilized cell. For if we must regard the sperm as real cells no less than the ova, and the process of conception of the two

under the microscope, it bears in and independent organism.

It bears in the cell and nuclear matter of the penetrating spermatozoon a part of the father's body, and in the protoplasm and cytoplasm of the ovum a part of the mother's body. This is clear from the fact that the child inherits many features from both parents. It inherits from the father by means of the spermatozoon, and from the mother by means of the ovum. The

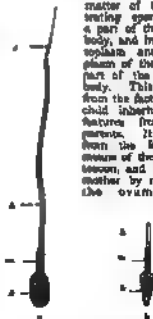


FIG. 22.—A single human spermatozoon magnified 1000 times. a, shown a from the broader end b from the narrower side. c head (with nucleus), m middle-piece, k long section, and s tail. (From Zerk.)

actual blending of the two cells produces a third cell, which is the germ of a child, or the new organism conceived. One

is that the stem-cell is a single germ-cell; it unites both sexuals in itself.

I think the fundamental importance of this is but often unappreciated, features in order to have a correct and clear idea of conception. With that end, I have given a special name to the new cell from which the child develops, and which is generally loosely called "the fertilized ovum," or "the first segmentation sphere." I call it "the stem-cell" (*zygote*). The name "stem-cell" seems to me the simplest and most suitable, because all the other cells of the body are derived



FIG. 15.—The Germ

li, and because

mother and stem-mother of all the countless generations of cells of which the multicellular organism is to be composed. That complicated molecular movements of the protoplasmic

thing quite differs

what we find in the two parent-cells, from the coalescence of which it has issued. The life of the stem-cell or zygote is the product or result of the paternal life-movement that is conveyed in the spermatozoon, and the maternal life-movement that is contributed by the ovum.

The admirable work done by

animals, commencing with the formation

of a single "stem-cell" of this cell, and that this then passes, by repeated segmentation (or cleavage),

known as "the segmentation sphere" or "segmentation cell." The process is most clearly observed in the ova of the echinoderms (star-fishes, sea-urchins, etc.). The investigators Oscar and Richard Hertwig were chiefly directed to these. The main results may be summed up as follows:—

Conception is preceded by certain preliminary changes, which are very necessary—in fact, usually indispensable—for its occurrence. They are comprised under the general heading of "Changes prior to impregnation." In these the original

sphere of the ovum, the germinal vesicle, is lost. Part of it is extruded, and part dissolved in the cell contents; only a very small part of it is left to form the basis of a fresh nucleus, the *pro-nucleus* forming it is the latter alone that contains the conception with the invading nucleus: the fertilizing spermatozoon (the *pro-nucleus*).

The impregnation of the ovum commences with a fusion of the germinal vesicle, or the original nucleus of the ovum (Fig. 6). We have seen that this is a mass enclosed in a large, transparent, fluid vesicle. This germinal vesicle contains a viscous fluid (the *cytoplasm*). The firm nuclear frame (*carionema*) is formed of the surrounding membrane and a network of nuclear threads running across the interior, which is filled with the nucleoplasm. In a knot of the network is contained the dark, stiff, opaque nuclear compound or nucleolus. When the impregnation of the ovum begins, the greater part of the germinal vesicle is dissolved in the cell, the nuclear membrane and network disappear, the nucleolus is distributed in the protoplasm, a small portion of the nuclear base is extruded, another small

condary

female pro-nucleus (Fig. 24 & 8)

The small portion of the nucleus which is extruded from the impregnated ovum is known as the "derivative bodies" or "polar cells"; there are many disputes as to their origin and significance, but

they

small granules, of which appear on the remaining pro-nucleus. They are detached cell-bodies; their separation from the large nucleus takes

place in the same way as in ordinary "indirect cell-division." Hence, the polar cells are probably to be considered as "abortive ova," or "rudimentary ova," which proceed from a single ovum by cleavage in the same way that several sperm-cells arise from one "sperm-mother-cell," in reproduction from spores. The male sperm-cells in the testicles must undergo similar changes in view of the

the ova in the maturing of the each of the original seed-cells by dividing segmentation into six daughter-cells, each furnished with fourth of the original nuclear matter (the hereditary chromatin), and each of these

pendant cells become *spermatozoa*, ready for impregnation. Thus, is prevented the doubling of the chromatin in the coalescence of the two nuclei at conception. As the two polar cells are extruded and lost, and have no further part in the fertilization of the ovum, we need not discuss them any further. But we must give more attention to the female pro-nucleus which alone remains after the polar cells and the chromatin is lost (Fig. 23 & 4) composed of chromatin the of attraction for the

male pro-nucleus. The product of the blending, which is the most important part of the act of impregnation, is the

subsequent embryonic processes.

Harrison just shows that the tiny transparent ova of the echinoderms are the

of this important
We can, in this
fully accomplish
and follow the

up by step within the space of ten minutes. If we put ripe ova of the starfish

fluid, we find each ovum within five minutes. Then

described as "sperm-threads" (Fig. 20), take their way to the ova, owing to a sort of chemical revision action which may be called "swell." But only one of

these immotile spermatozoa is chosen—usually, the one that first reaches the ova by the serpentine motions of its tail, and attaches the ovum with its head.

the spot where the touches the surface of the ovum the protoplasm of the latter is raised in the form of a small wart, the "impregnation rim" (Fig. 25 A). The spermatozoon then bores its way into this with its head, a tail outside wriggling about all the as (Fig. 25 B, C). Presently the tail disappears within the ovum. At the same time the ovum secretes a thin external yolk-membrane (Fig. 25 C), starting from the point of impregnation, so this prevents any more spermatozoa

Inside the impregnated (as a rapid series of

The pear-shaped head of the

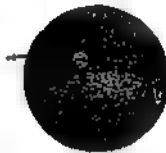


Fig. 24—An impregnated echinoderm ovum and spermatozoon inside (24) (The

son," grows larger and round is connected with the male pro- (Fig. 26 & 2) This has an nt in the center of the fine granules

They move towards each other inside the yolk with increasing speed, the

male nucleus takes with it the radiat into which spreads like a star about i ch (usually in the centre of the globular ovum), lie close together, are flattened at the points of contact and coalesce into a common mass. The small central particles of

nuclei which is formed from this combination of the nuclei is the stem-nucleus or the first segmentation nucleus; its new-formed cell, the product of this impregnation, is our stem-cell, or "first segmentation sphere" (Fig. 2).

Hence the one essential point in the process of actual reproduction.

From the stem-cell, the further development of the organism, the further away to be drawn that the male nucleus conveys to the child the qualities of the father, and the female nucleus the features of the mother. We must not forget, however, that the protoplasmic bodies of the copulating cells also fuse together in the act of impregnation; the cell-body of the invading spermatozoon (the trunk and all of the male ciliated cell) is dissolved in the yolk of the female ovum, and thus forms a very careful

nucleus the function of general... level, and to the nutritive protoplasm the duties of nutrition and adaptation. As, moreover, there is a complete combination of the mutually attracted nuclear substances in conception, and the new nucleus formed (the stem-nucleus) is the

starting-point for the development of the future organism, the further away to be drawn that the male nucleus conveys to the child the qualities of the father, and the female nucleus the features of the mother. We must not forget, however, that the protoplasmic bodies of the copulating cells also fuse together in the act of impregnation; the cell-body of the invading spermatozoon (the trunk and all of the male ciliated cell) is dissolved

in the yolk of the female

ovum to form a very careful



FIG. 2.—Fertilization of the ovum of a star-fish. (From Huxley.) Only a small part of the ovum is shown. One of the numerous spermatozoa approaches the "egg" (A), and then penetrates into the protoplasm of the ovum (B).

study of the rise and structure of the stem-cell.

The first question that arises is as to the behaviour of the two different active elements, the nucleus and the protoplasm.

It is obvious that the nucleus plays the more important part in this. Hence Huxley puts his theory of conception in the principle: "Conception consists in the copulation of two cell-nuclei, which come from a male and a female cell." And so the phenomenon of heredity is inseparably connected with the reproductive process, we may further conclude that these two copulating nuclei "convey the characteristics which are transmitted from parents to offspring." In this sense I had in 1886 (in the ninth chapter of the *General Morphology*) ascribed to the reproduction

the nuclei, but it must not be overlooked that

through the fusion of the two nuclei, we see clearly at least the formation of the star-like figure (the radial arrangement of the particles in the plasma) in it (Figs. 26-27).

The older theories of impregnation generally went astray in regarding the large ovum as the sole basis of the new organism, and only ascribed to the spermatozoon the work of stimulating and originating its development. The stimulus which it gave to the ovum was sometimes thought to be purely chemical, at other times rather physical (on the principle of transferred movement), or again a psychic and transcendental process. This error was partly due to the imperfect knowledge at that time of the facts of impregnation, and partly to the striking

difference in the size of the two sexual cells. Most of the earlier observers thought that the spermatozoon did not penetrate into the ovum. And even when this had been demonstrated, the spermatozoon was believed to disappear in the ovum without leaving a trace. However, the splendid research made in the last three decades with the finer technical methods of our time has completely exposed the error of this. It has been shown that the tiny sperm-cell is not subordinated to, but co-ordinated with, the large ovum. The nuclei of the two cells, as the vehicles of the hereditary features of the parents, are of equal physiological importance. In some cases we have succeeded in proving that the mass of the active nuclear substance which contributes to the constitution of the new

The striking difference of the respective sexual cells in size and shape, which occasioned the erroneous views of earlier scientists, are easily explained on the principle of division of labour. The inert, stationary ovum grows in size according to the quantity of provision it stores up in the form of nutritive yolk for the development of the germ. The active swimming sperm-cell is reduced in size in proportion to its need to seek the ovum and bore its way into its yolk. These differences are very conspicuous in the higher animals, but they are much less in the lower animals. In those countless (unclassified plants and animals) which have the first rudiments of sexual reproduction the two copulating cells are at first quite equal. In these cases the act of insemination is not followed by a

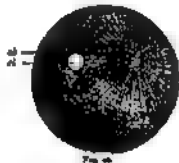


Fig. 1. Impregnation of the ovum of the sea urchin. The small white circle on the left is the nucleus of the spermatozoon, the large circle on the right is the nucleus of the ovum.



Fig. 2. Impregnation of the ovum of the sea urchin. The small white circle on the left is the nucleus of the spermatozoon, the large circle on the right is the nucleus of the ovum.

sexual nuclei is originally the same for both.

These morphological facts are in perfect harmony with the familiar physiological truth that the child inherits from both parents, and that on the average they are equally distributed. I say "on the average," because it is well known that a child may have a greater likeness to the father or to the mother; that goes without saying, so far as the primary sexual characters (the sexual glands) are concerned. But it is also possible that the determination of the latter—the weighty determination whether the child is to be a boy or a girl—depends on a slight qualitative or quantitative difference in the nucleus or the coloured nuclear matter which which comes from both parents in the act of conception.

sudden growth, in which the originally anisoploid cell doubles its volume, and is then prepared for reproduction (cell-division). Afterwards slight differences are seen in the mass of the copulating cells; though the smaller ones still have the same shape as the larger ones. It is only when the difference in size is very pronounced that a notable difference in shape is found: the sprightly sperm-cell changes more in shape and the ovum

grows on in size. With this view of the conception of the spermatozoon of the two gametes, or the equal physiological importance of the male and female sex-cells and their equal share in the process of heredity, is the important fact established by Hertwig (1875), that in normal impregnation only one single spermatozoon

equilibrium with one ovum; the membrane which is raised on the surface of the yolk immediately after one sperm-cell has penetrated (Fig. 23 C) prevents any others from entering. All the trials of the fortunate penetrator are exhausted, and die without. But if the ovum passes into a moribund state, if it is made stiff by a lowering of its temperature or stupefied with narcotics (chloroform, morphine, nicotine, etc.), two or more spermatozoa may penetrate into its yolk-body. We then witness *polypermum*. The more Hertwig chloroformed the ovum, the spermatozoa were able to leave it conscious body.

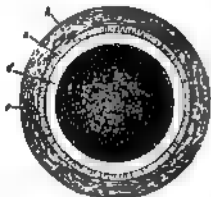


FIG. 23.—Sperm-cell of a rabbit, regarded as fungus. In the center of the granular protoplasm of the nucleus which fills in most the left, bright clear patches, it is the developing embryo. The outer membrane (a) is a cell wall, spermatozoa.

These remarkable facts of *imagination* in polypermum, especially as regards the theory of the cell-nuclei, which I consider to be its chief foundation. The phenomena we and explained by attributing mental degree of psychic activity to the principles. They *feel* each other's duty, and are drawn to the few impulse (probably related to mind); they move towards each other, and do not until they fuse together. Physiologists may say that it is only a question of a peculiar physico-chemical phenomenon, and that a psychic action, even the two cannot be separated. Even the psychic functions, in the strict sense of the word, are only complex physical

processes, or "psycho-physical" phenomena, which are determined in all cases exclusively by the chemical composition of their material substratum.

The monistic view of the matter becomes clear enough when we remember the radical importance of *imagination* as regards heredity. It is well known that not only the most delicate bodily structures, but also the subtlest traits of mind, are transmitted from the parents to the children. In this the chromatic matter of the male nucleus is just as important as vehicle as the large cytoplasmic vehicle

and the other elements of the mother. blending of the two parental nuclei determines the individual psychic character of the child.

But there is another important psychological quantum—the most important of all—has been definitely answered by the recent discoveries in connection with conception. This is the quantum of the *monism* of the soul. No fact throws more light on it and refutes it more convincingly than the extraordinary process of conception that is here described. For the copulation of the two sexual nuclei (Fig. 20-27) initiates the process moment in which the individual begins to exist. All the bodily and mental features of the newborn child are the summation of the hereditary qualities which it has received in reproduction from parents and ancestors. All that man inherits afterwards in life by the exercise of his organs, the influence of his environment, and education—in a word, by adaptation—cannot obliterate that general outline of his being which he inherited from his parents. But this hereditary disposition, the essence of every human soul, is not "accidental," but "temporal," it comes into being only at the moment when the sperm-nucleus of the father and the nucleus of the maternal ovum meet and fuse together. It is clearly impossible to assume an "eternal life without end" for an individual phenomenon, the commencement of which we can indicate to a moment by direct visual observation.

The great importance of the process of *imagination* in answering such questions is quite clear. It is true that studied especially in all its details in the human mind—understanding its occurrence at any moment—for example that are

various enough. However, the two cells which need consideration, the female oocyte and the male spermatozoon, proceed in

in all the other mammals, the human fetus or embryo which results from copulation has the same form as with the other animals. Hence, an scientist who is acquainted with the facts doubts that the processes of impregnation are just the same in man as in the other mammals.

The stem-cell which is produced, and with which every man begins his career, cannot be distinguished in appearance from those of other mammals, such as the rabbit (Fig. 2B). In the case of man, also, this stem-cell differs materially from the original ovum, both in regard to form (morphologically), in regard to material composition (chemically), and in regard

to vital properties (physiologically). It is partly from the father and partly from the mother. Hence it is not surprising that the child who is developed from it inherits from both parents. The vital movements of each of these cells form a sum of mechanical processes which in the last analysis are due to movements of the smallest vital parts, or the molecules, of the living substance. If we agree to call this active substance *plasma*, and its molecules *plastules*, we may say that the individual physiological character of each of these cells is due to its molecular plastidule-movement. Hence, the *plastidule-movement of the ovule is the resultant of the combined plastidule-movements of the female ovum and the male sperm-cell.*

CHAPTER VIII.

THE GASTREA THEORY

There is a substantial agreement throughout the animal world in the first changes which follow the impregnation of the ovum and the formation of the stem-cell; they begin in all cases with the segmentation of the ovum and the formation of the germinal layers. The only exception is found in the protozoa, the very lowest and simplest forms of animal life; these remain unicellular throughout life. To this group belong the amoeba, paramecium, rhizopoda, infusoria, etc. As their whole organism consists of a single cell, they can never form germinal layers, or definite strata of cells. But all the other animals—all the tissue-forming animals, or metazoa, as we call them, in contradistinction to the protozoa—construct real germinal layers by the repeated cleavage of the impregnated ovum. This we find in the lower cnidaria and worms, as well

as in the more highly-developed molluscs, echinoderms, articulates, and vertebrates.

In all these metazoa, or multicellular animals, the chief embryonic processes are substantially alike, although they often seem to a superficial observer to differ considerably. The stem-cell that proceeds from the impregnated ovum always passes by repeated cleavage into a number of acropl cells. These cells are all direct descendants of the stem-cell, and are, for reasons we shall see presently, called segmentation-cells. The repeated cleavage of the stem-cell, which gives rise to these segmentation-spheres, has long been known as "segmentation." Sooner or later the segmentation-cells join together to form a round (or first, globular) embryonic sphere (*blastula*); they then form into two very different groups, and arrange themselves

¹ The plasma of the stem-cell or ovule may, from the practical point of view, be regarded as homogeneous and structureless, like that of the amoeba. This is not inconsistent with our hypothetical ascription to the plastidule (or molecules of the plasma) of a complex molecular structure. The complexity of this is the greater in proportion to the complexity of the organism that is developed from it and the length of the chain of its ancestry, or to the number of antecedent processes of heredity and adaptation.

in two opposite states—the two primary germinal layers. These contain a digestive cavity, the primitive gut, with an opening, (the primitive mouth). We give the name of the gastrula to the important embryonic form that has these primitive organs, and the name of gastrulation to the formation of it. This embryonic process has a very great significance, and is the real starting-point of the construction of the multicellular animal body.

The fundamental embryonic passages of the cleavage of the ovum and the formation of the gastrula have been very thoroughly studied in the last thirty years, and their real significance has been appreciated. They present a striking variety in the different groups, and it was no light task to give a few general ideas of the whole animal world. But now I formulated the gastrula theory in 1875, and afterwards (1877) reduced all the various forms of gastrulation and gastrulation to one fundamental type, their meaning may be said to have been established. We have thus ascertained the law of unity which governs the first embryonic processes in all the animals.

Man is like all the other higher animals, especially the ape, in regard to these earliest and most important processes. As the human embryo does not essentially differ, even at its most later stage of development—when we already perceive the cerebral vesicles, the eyes, ears, gill slits, etc.—from the younger forms of the other higher mammals, we may confidently assume that they agree in the earliest embryonic processes, gastrulation and the formation of gastrula type. This has not yet, it is true, been established by observation. We have, however, had occasion to discuss a certain (secondary) after-impregnation and therefore the inner-cell or the gastrulation-cells in her subject. However, in the earliest human embryos we have observed, and the later and more developed forms, agree with those of the rabbit, dog and other higher mammals, no reasonable man will doubt but that the gastrulation and formation of layers are the same in both cases.

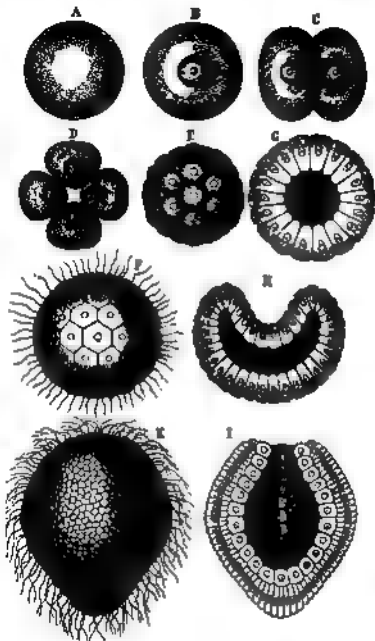
But the special laws of gastrulation and layer formation which we find in the mammal is by no means the original, simple, palaeozoic form. It has been much modified and consequently

altered by a very complex adaptation to embryonic conditions. We cannot, therefore, understand it altogether in itself. In order to do this, we have to make a comparative study of gastrulation and layer-formation in the animal world; and we have especially to seek the original, palaeozoic form from which the modified mammalian (and p.) form has gradually been developed.

This original unmodified form of gastrulation and layer-formation is found today in only one case in the vertebrates, in which man belongs—the lowest and simplest member of the class, the wonderful lancelet or amphioxus (cf. Chapter XVI and XVII). But we find a previously similar palaeozoic form of embryonic development in the case of many of the invertebrate animals, as, for instance, the remarkable oozoid, the sand-dollar (*Lamproloma*), the green-stem (*Agaritia*) and many of the actinopores and radiata, such as the scyphozoan strobila and swimmers, many of the medusae and combs, and the simple sponges (*Cyanea*). We may take as an illustration the palaeozoic gastrulation and germinal layer-formation in an eight-fold star coral, which I discovered in the Red Sea, and described as *Alcyonium Loricatus*.

The impregnated ovum of this coral (Fig. 10, A) first splits into two equal cells (B). First, the nucleus of the inner-cell and its several body divide into two halves. These divide first and equal each other, and not as centres of attraction on the surrounding protoplasm, as consequences of this, the protoplasm is invaginated by a circular furrow, and, in turn, divides into two halves. Each of the two gastrulation-cells then produced splits in the same way into two equal cells. The four gastrulation-cells (grand-daughters of the inner-cell) lie in one plane. Now, however, each of them subdivides into two equal halves, the daughter of the nucleus again protruding out of the surrounding protoplasm. The eight cells which thus subdivide into sixteen, then into thirty-two, and then (each having constantly halved) into sixty-four, 128, and so on.* The final result of this

* The number of gastrulation-cells first produced depends essentially on the original proportion of the parent protoplasmic mass of the ovum. However, it is almost always the number sixteen, a different number only in the species and also in the stage, say in the case of the oozoid, radiata, etc. of many forms and members of all or some, etc.



61. Gastrulation of a coral (*Alcyonium* *horridum*). A, B, two-cell (zygote or unsegmented ovum). C, immediately after unsegmented the ovum is visible. In Fig. 70, both blastoderm and gutt clear. C, symmetrical cells. D, four quadrants cells. E, eight quadrants cells. F, sixteen quadrants cells. G, thirty-two quadrants cells. H, sixty-four quadrants cells. I, gastrula (longitudinal section). K, gastrula, or sup-optical, external appearance.

repeated change in the formation of a globular cluster of smaller organism-cells, which we call the *multicelluliferous* or *marula*. The cells are thickly pressed together like the parts of a mulberry or blackberry, and this gives a bumpy appearance to the surface of the sphere (Fig. E).

When the change is thus ended the multicelluliferous mass changes into a hollow globular sphere. Watery fluid or jelly gradually fills the cavity, the organism-cells are loosened, and all run to the surface. There they are flattened by mutual pressure, and arrange themselves side by side in one regular layer (Fig. F, G). This layer of cells is called the *germinating blastodermis* (or *blastoderm*). The hollow-sphere cells which compose the simple water-bag are called the *blastodermis cells*; and the whole hollow sphere, the walls of which are made of the preceding, is called the *Marula* or *Amphiblastula*.

In the case of our great and of many other lower forms of animals like the young embryo begins to move independently and even glides in the water. A hair, long, thread-like process, a part of which or both, grows out of each blastodermis cell, and these independently execute a wavy undulating motion, now at first, but quicker after a time (Fig. F). In this way the blastodermis cell becomes a ciliated cell. The combined force of all these waving motion causes the whole Marula to move about as a vapour bubble. In every other creature, especially those in which the embryo develops within a closed environment, the ciliated cells are only formed at a later stage, or even not formed at all. The blastodermis thus grow and expand by the blastodermis cells (at the surface of the sphere) dividing and increasing, and more fluid is secreted in the internal cavity. There are still to-day some organisms that remain throughout life at this structural stage of the Marula—hollow spheres that swim about by a diffusive movement in the water.

The wall of which is composed of a single layer of cells, such as the valves, the megasphores, spines, etc. We shall speak further of the great physiological significance of this fact in the subsequent Chapter.

A very important and remarkable process now follows—namely, the *curving* or *invagination* of the Marula (Fig. H). The wall with a single layer of cells for wall is converted into a bag with a wall of two layers of cells (cf. Figs. L, M, N). A dent is put at the surface of the sphere to flatten it, and then bent inward. This depression sinks deeper and deeper, growing at the end of the internal cavity. The latter deepens into the hollow interior. At last the internal cavity deepens altogether the larger side of the blastoderm (that is much later the depression) coming to be open on the outer side. At the same time the cells of the two opposite corners flatten into rods and sheets. The lower cells are more rounded and the upper more oval (Fig. I). In this way the embryo takes the form of a cup or jar-shaped body, with a wall made up of two layers of cells the inner cavity of which opens to the outside at one end (the spot where the depression was originally formed). We call this very important and interesting embryonic form the "*cup-embryo*" or "*cupula*" (Fig. J, longitudinal section, a natural view). I have in my *Natural History of Creation* given the name of *diapoda* to the remarkable intermediate form which appears at the passage of the Marula into the gastrula. In this intermediate stage there are two cavities in the embryo—the original cavity (*blastocoel*) which is disappearing, and the primitive gut-cavity (*proctocoel*) which is forming.

I regard the gastrula as the most important and significant embryonic form in the animal world. In all real animals (that is, excluding the amorphous protists) the organization of the young produces either a pure, primitive, polygastric gastrula (Fig. on L, M) or an equally distinctive megagastric form, which has been developed in time from the first, and can be directly reduced to it. It is certainly a fact of the greatest interest and importance that animals of the most different ranks—vertebrates and rudiments, molluscs and arthropods, celenterates and annelids, insects and spores—pass from one and the same embryonic form. In illustration I give a few

1. The organism-cells which make up the mass after the close of the multicelluliferous stage, must usually be quite smaller, and be joined to the embryo or to the Marula, or to the gastrula. That, however, does not prevent them from differentiating into ciliated and vegetative cells even during the change.

2. The Marula of the lower animals must be distinguished from the very different Marula of the vertebrates, which is originally called the gastrula or blastodermis. The gastrula gastrulae are the gastrulae of the vertebrates, and the gastrulae of the lower animals are the gastrulae of the lower animals.

pure gastrula forms from various groups of animals (Figs. 30-35, explanation given below each).

In view of this extraordinary significance of the gastrula, we must make a very careful study of its original structure. As a rule, the typical gastrula is very small, being invisible to the naked eye, or

half round, or even almost round, and in others longitudinal cut, or almost cylindrical.

I give the name of primitive gut (*pro-gut*) and primitive mouth (*protoma*) to the internal cavity of the gastrula-body and its opening, because this cavity is the first rudiment of the digestive cavity of

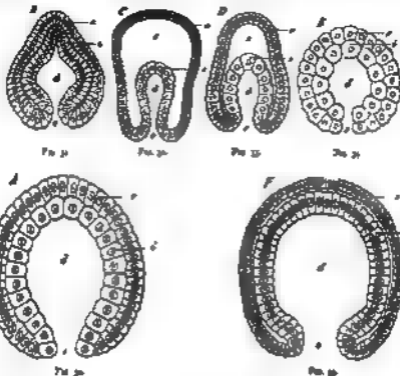


Fig. 30 (A).—Gastrula of a very simple primitive gut animal or gastrula (triphlebotoma) (Haeckel.)

Fig. 31 (B).—Gastrula of a worm (Sipho). (From Haeckel's work.)

Fig. 32 (C).—Gastrula of an embryonic (triphlebotoma, triphlebotoma) not completely divided in (triphlebotoma). (From Haeckel's work.)

Fig. 33 (D).—Gastrula of an embryonic (triphlebotoma) (Haeckel's work.)

Fig. 34 (E).—Gastrula of a mollusk (triphlebotoma) (Haeckel's work.)

Fig. 35 (F).—Gastrula of a vertebrate (triphlebotoma) (Haeckel's work.) (From Haeckel's work.)

In each figure a = the primitive gut cavity, b = primitive mouth, c = primitive gut cavity, d = primitive gut cavity, e = primitive gut cavity, f = primitive gut cavity, g = primitive gut cavity, h = primitive gut cavity, i = primitive gut cavity, j = primitive gut cavity, k = primitive gut cavity, l = primitive gut cavity, m = primitive gut cavity, n = primitive gut cavity, o = primitive gut cavity, p = primitive gut cavity, q = primitive gut cavity, r = primitive gut cavity, s = primitive gut cavity, t = primitive gut cavity, u = primitive gut cavity, v = primitive gut cavity, w = primitive gut cavity, x = primitive gut cavity, y = primitive gut cavity, z = primitive gut cavity.

at the most only visible as a fine point under very favourable conditions, and measuring generally $\frac{1}{16}$ to $\frac{1}{8}$ of an inch (less frequently $\frac{1}{8}$ inch, or even more) in diameter. In shape it is usually like a roundish drinking-cup. Sometimes it is rather oval, at other times more ellipsoid or spindle-shaped; in some cases it is

the organism, and the opening originally serving to take food into it. Naturally, the primitive gut and mouth change very considerably afterwards in the various classes of animals. In most of the coelomates and many of the annelids (worm-like animals) they remain unchanged throughout life. But in most of the

[identity] of the primary germinal layers and the primitive gut "has been confirmed during the last thirty years by the careful research of many able observers, and is now pretty generally admitted for the whole of the Metazoa.

As a rule, the cells which compose the two primary germinal layers show appreciable ^{cellular} differences at an early stage. Generally (if not always) the cells of the skin-layer or ectoderm (Figs. 36c, 37c) are the smaller, more numerous,

layer, or entoderm (s), are larger, less numerous, and darker. The precursor of the ectodermic (outer) cells is close

matter of the entodermic (inner) cells, the latter are, as a rule, much richer in yolk-granules (alburnin and fatty particles) than the former. Also the cells of the yolk-layer have, as a rule, a stronger affinity for colouring matter and take on a tinge in a solution of carmine, aniline, etc., more quickly and appreciably than the cells of the skin-layer. The nuclei of the entoderm-cells are usually rounded, while those of the ectoderm-cells are oval.

When the doubling-process is complete, very striking histological differences between the cells of the two layers are found (Fig. 37). The inner, hypertrophic cells (e) are sharply distinguished from the larger and darker entoderm-cells (s). Frequently this differentiation of the cells is not in its very early stage, during

very appreciable in the blastula.

We have, up to the present, considered that form of segmented gastrulation which, for many and weighty reasons, we may regard as the original, primitive, or paleogastric form. We

segment

resemblance to each other at first (and often with the formation of the blastoderm). We give the name of the "bell-gastrula," or *archigastrea*, to the gastrula that succeeds it. In just the

Fig. 29), we find it in lowest zoophytes (the gastrophytes, Fig. 30) and the simplest sponges (polythous, Fig. 36); also in many of the medusae and hydras, lower types of worms of various classes (brachiopod, annel-worm, Fig. 31), tunicates (ascidians, many of the echinoderms (Fig. 32), lower articulates (Fig. 33), and molluscs (Fig. 34), and,

finally, in a slightly modified form, in the lowest vertebrates (the amphioxus, Fig. 35).

The gastrulation of the amphioxus is especially interesting because this lowest and oldest of all the vertebrates is of the highest significance in connection

of the vertebrate stem, a

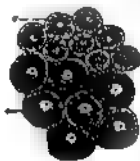
Chapter XVI. and XVII.). Just as the comparative anatomist traces the most elaborate features in the structures of the

vertebrates to divergent

element from this simple primitive

secondary forms of ve

formation of the germinal layers in the



amphioxus. Although this form is regarded from the ontogenetic standpoint

it can be regarded as paleogastric. It is quite different in many features from the quite primitive gastrulation such as we have, for instance, in the *Monaxonas* (Fig. 29) and the *Sagitta*. Hatschek rightly observes that the segmentation of the ovum in the amphioxus is not strictly equal, but almost equal, and approaches the unequal. The difference in size between the two groups of cells continues to be very noticeable in the further course of the segmentation; the smaller animal cells of the upper hemisphere divide more quickly than the larger vegetal cells of the (Fig. 38 A, B). The blastoderm, which forms the single-layer wall of the globular blastula at the end of the cleavage-process, does not consist of

homogeneous cells of equal size, as in the *Scaphisoma* and the *Alveolaria*; the cells of the upper half of the blastoderm (the mother-cells of the actinoderm) are more numerous and smaller, and the cells of the lower half (the mother-cells of the ovaroderm) less numerous and larger. Moreover, the segmentation-cavity of the blastula (Fig. 38 C, A) is not quadrilateral, but forms a flattened upwardly with unequal poles of its vertical axis. While the blastula is being folded into a cup at the vegetal pole of its axis, the difference in the size of the blastodermic cells increases (Fig. 38 D, B); it is more conspicuous when the blastula is complete and the segmentation cavity has

the blastoderm (or the lacunas of its cells) being broader on one side than on the other: the side that grows more quickly, and so is more curved (Fig. 38 E), will be the superior or belly-side, the opposite, flatter side will form the back (A). The primitive mouth, which at first, in the typical archigasterula, lay at the vegetal pole of the main axis, is forced away to the dorsal side; and whereas its two lips lay at first in a plane at right angles to the chief axis, they are now so far thrust aside that their plane cuts the axis at a sharp angle. The dorsal lip is therefore the upper and more forward, the ventral lip the lower and hinder. In the latter, at the central passage of the ovaroderm into

the actinoderm, there too side by side a pair of very large cells, one to the right and one to the left (Fig. 38 F); these are the enormous polar cells of the primitive mouth, or "the primitive cells of the ovaroderm." In consequence of these considerable variations, nothing in the course of the gastrulation, the primitive univalve form of the archigasterula in the amphioxus has already become trivalve, and thus the two-sidedness, or bilateral symmetry, of the vertebrate body has already been determined.

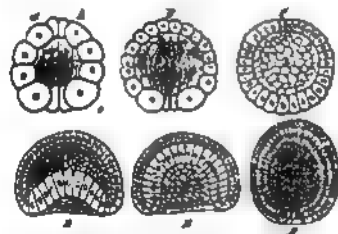


FIG. 38.—Development of the amphioxus from blastula to gastrula. A, B, C, D, E, F, show stages in the formation of the blastula. A, B, C, D, E, F, show stages in the formation of the gastrula. A, B, C, D, E, F, show stages in the formation of the gastrula. A, B, C, D, E, F, show stages in the formation of the gastrula.

disappeared (Fig. 38 F). The larger vegetal cells of the ovaroderm are richer in granules, and so darker than the smaller and lighter animal cells of the actinoderm.

But the temporal gastrulation of the amphioxus diverges from the typical animal cleavage of the *Scaphisoma*, the *Alveolaria* (Fig. 39), and the *Ophiaster* (Fig. 38). In another important particular. The pure archigasterula of the latter forms is univalve, and it is round in its whole length to transverse section. The vegetal pole of the vertical axis is just in the centre of the primitive mouth. This is not the case in the gastrula of the amphioxus. During the folding of the blastula the ideal axis is already bent on one side, the growth of

This has been demonstrated in amphioxus to all the other modified gastrula-forms of the vertebrate stem.

Apart from this bilateral structure, the gastrula of the amphioxus resembles the typical archigasterula of the lower animals (Figs. 38-39) in developing the two primary germinal layers from a single layer of cells. This is clearly the oldest and original form of the metazoan embryo. Although the animals I have mentioned belong to the most diverse classes, they nevertheless agree with each other, and many more animal forms, in having retained to the present day, by a conservative heredity, this primitive form of gastrulation which they have from their

earliest common ancestors. But this is not the case with the great majority of the animals. With these the original embryonic process has been gradually less altered in the course of

time clearly be distinguished from the formative plasma. As a rule, the formative-yolk (with the germinal vesicle) then usually gathers at one pole and the food-yolk at the other. The first is the animal, and the second the vegetal, pole of the

segmentation of the ovum and the subsequent gastrulation have in this way been considerably changed. In fact, these various

the course of it was not rightly understood animals, and the gastrula was misapprehended. It was not until I had made an extensive comparative study, tracing a considerable time (in the years 1886-93), in journals of the most diverse character, that I succeeded in showing the same common typical processes in these apparently very different forms of gastrulation, and tracing them all to two original forms. I regard all those that diverge from the primary pallogenic gastrulation as secondary, modified, and anaplastic. The more or less divergent form of gastrula that is produced may be called a secondary, modified gastrula, or a metagastrea. The reader will find a scheme of these different kinds of segmentation gastrulation at the close of this paper.

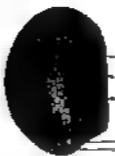
By far the most important process that determines the various convergent forms of gastrulation is the change in the nutrition of the ovum and the assimilation in it of nutritive yield. By this we understand various chemical substances (chiefly granules of albumen and lecithin) which serve exclusively as reserve-material or food for the embryo. As the metazoic embryo in its earlier stages of development

draws its food and so build up the tissues, the necessary material has to be stored up in the ovum. Hence we distinguish in the ovum two chief elements—the active formative yolk (protoplasm) and the passive food-yolk (dermatoplasm, wrongly spoken of as "the yolk"). In the little pallogenic ovum, the segmentation of which we have already considered, the yellow granules are so small and so uniformly distributed in the protoplasm of the ovum

the even and repeated cleavage is not affected by them. But in the great majority of the animal ovum the food-yolk is more or less considerable, and is stored in a certain part of the ovum, so that even in the unfertilized ovum the "gastrula"

can clearly be distinguished from the formative plasma. As a rule, the formative-yolk (with the germinal vesicle) then usually gathers at one pole and the food-yolk at the other. The first is the animal, and the second the vegetal, pole of the

way that in the cleavage of the impregnated ovum the animal (usually the upper) half splits up more quickly than the vegetal (lower). The contractions of the active protoplasm, which effect this continual change of the cells, meet a greater resistance in the lower vegetal half from the passive dermatoplasm than in the upper animal half. Hence we find in the latter



The gastrula of the amphibia, seen from below. The dermatoplasm (from the animal) is a plasma for gastrula, and the

cell is smaller, and in the former fewer but larger, cells. The central cells pro-

duce the internal, germinal layer.

Although the unequal segmentation of the cyclostoma, graptolite, and amphibia seems at first sight to differ from the original equal segmentation (for instance, in the mammalia, Fig. 89), they both have this in common, that the cleavage process throughout affects the whole cell, hence I have called it total segmentation, and the ovum in question holoblastic, or "whole-cleaving." It is otherwise with the second chief group of ova, which I distinguished from these as meroblastic, or "partially-cleaving": in this class belong the familiar large eggs of birds and reptiles, and of most fishes. The first mass of the passive food-yolk is so

large in those cases that the protoplasmic symmetries of the entire yolk cannot affect any further cleavage. In consequence, there is only a partial segmentation. While the protoplasm in the animal division of the ovum continues actively to divide, multiplying the nuclei, the development in the vegetal section remains more or less undisturbed, it is merely concerned as food by the forming cells. The larger the accumulation of food, the more restricted is the process of segmentation. It may, however, continue for some time (even after the gastrulation is more or less complete) in the sense that the vegetal cell-mass distributed in the blastopore slowly narrows by cleavage: as much of them is surrounded by a small quantity of protoplasm, it may afterwards appear just a portion of the food-yolk, and thus form a real "yolk-cell" (*macula*). When this typical cell-formation commences for a long time, after the two primary germinal layers have been formed, it takes the form of the "after-segmentation."

The meroblastic ova are only found in the larger and more highly developed animals, and only in those whose embryonic mode of development and whose meroblastic nature within the local environment. According to the yolk-food accumulation at the centre or at the side of the ovum, we distinguish two groups of developing ova, parietal and discoidal, in the parietal the function is in the centre, enclosed inside the ovum (hence they are also called "centralized" ova); the parietal yolk surrounds the food-yolk, and so suffers itself a superficial cleavage. This is found among the arthropods (insects, spiders, insects, etc.). In the discoidal ova the food-yolk gathers at one side, at the vegetal or lower pole of the vertical axis, while the nucleus of the ovum and the great bulk of the formative yolk lie at the upper or animal pole (hence these ova are also called "subcentral"). In these cases the cleavage of the ovum begins at the upper pole, and leads to the formation of a dorsal double embryo. This is the case with all meroblastic vertebrates, most fishes, the reptiles and birds, and the cephalopod mollusks (the nautilus).

The gastrulation of the discoidal ova, which chiefly concerns us, offers serious difficulties to microscopic investigation and photogenic reproduction. These, however, have been mastered by

the comparative embryological research which has been conducted by a number of distinguished observers during the last few decades—especially the brothers Hertwig, Kold, Kugler, Illenow, Ruckert, Grosse, Kähler, etc. These thorough and careful studies, aided by the most perfect modern improvements in technical method (in fixing and dissection), have given a very accurate picture of the views which I put forward in my work, *On the Gastrula and its Segmentation of the Animal Ova* (not translated) in 1893. As it is very important to understand them clearly and their phylogenetic foundation clearly, not only as regards evolution in general, but particularly in connection with the question of race, I will give here a brief statement of them as far as they concern the gastrulation stage.

1. All the gastrulation, including that, are phylogenetically (or genealogically) related—that is, the members of one single natural group.

2. Consequently, the embryonic nucleus in these earliest developmental stage also has a generic connection.

3. As the gastrulation of the arthropods shows the typical paleontological form in its simplest structure, that of the other gastrulation must have been derived from it.

4. The gastrulation modification of the latter also starts appear while the animal food-yolk is stored up in the ovum.

5. Although the mass of the food-yolk may be very large in the ovum of the discoidal vertebrates, nevertheless in every case a blastula is developed from the nucleus, as in the holoblastic ova.

6. Next, in every case, the gastrula develops from the blastula by cutting off invaginations.

7. The cavity which is produced in this fashion by the cutting in, in each case, the primitive gut (*gut-tube*), and so opening the primitive mouth (*stomach*).

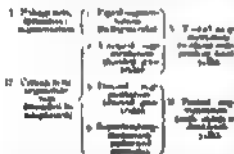
8. The food-yolk, whether large or small, is always stored in the central wall of the primitive gut; the cells (called "mesoderm") which may be formed in it subsequently (by "after-segmentation") also belong to the inner germinal layer, like the cells which immediately surround the primitive gut-tube.

9. The primitive mouth, which at last lies below at the lower pole of the vertical axis, is formed by the growth of the yolk, backward and then upward,

towards the dorsal side of the embryo; the vertical axis of the primitive gut is thus gradually converted into horizontal.

10. The primitive mouth is closed sooner or later in all the vertebrates, and does not evolve into the permanent mouth-aperture; it rather corresponds to the "propratorium," or region of the anus. From this important point the formation of the middle germinal layer proceeds, between the two primary layers.

The wide comparative studies of the animals I have named have further shown that in the case of the discriminate higher vertebrates (the three classes of animals) the primitive mouth of the gastrulae stage, which was long hindered for its exit, is found always and is nothing else than the function "peristaltic anus." Of this we shall see more in my new book. Meanwhile we realize that gastrulation may be reduced to one and the same process in all the vertebrates. Moreover, the various forms it takes in the invertebrates can always be reduced to one of the four types of gastrulation described above. In relation to the distinction between head and portal gastrulation, the grouping of the various forms is as follows:—



The lowest animals we know—namely, the lower amoeba (in sponges, mangrove polyps, etc.)—remain throughout life in a stage of development which differs little from the gastrula; their whole body consists of two layers of cells. This is a fact of extreme importance. We see that man, and also other vertebrates, pass quickly through a stage of development in which they consist of two layers, just as these low or amoeboid animals do throughout life. If we apply our biogenetic law to the matter, we at once reach this important conclusion: "Man and all the other animals which pass through the two-layer stage,

or gastrula-form, in the course of their embryonic development, must descend from a primitive simple stage-form, the whole body of which consisted throughout life (as is the case with the lower amoeboid today) merely of two cell-layers or germinal layers." We will call this primitive stage-form, with which we shall deal more fully later on, the *gastraea*—that is to say, "primitive-gut animal."

According to the gastrula-theory there was originally in all the multicellular animals one organ with the same structure and function. This was the primitive gut; and the two primary germinal layers which form its wall must also be regarded as identical in all. This important homology or identity of the primary germinal layers is proved, on the one hand, from the fact that the gastrula was originally formed in the same way in all animals—namely, by the curving of the blastula; and, on the other hand, by the fact that in every case the same fundamental organs arise from the germinal layers. The outer or animal layer, or ectoderm, always forms the chief organs of animal life—the skin, nervous system, sense-organs, etc.; the inner or vegetal layer, or endoderm, gives rise to the chief organs of vegetative life—the organs of nutrition, digestion, blood-formation, etc.

In the lower amoeba, whose body remains at the two-layer stage throughout life, the gastraea, the simplest organism (*Obolus*), and polyp (*Hydra*), have two groups of functions, several other vegetative ones strictly divided between the two simple primary layers. Throughout life the outer or animal layer acts simply as a covering for the body, and accomplishes its movement and nutrition. The inner or vegetative layer of cells acts throughout life as a gut-lining, or nutritive layer of esterc canal, and often also yields the reproductive cells.

The best known of these "gastraea," or "gastrula-like animals," is the common fresh-water polyp (*Hydra*). The simplest of all the creatures, however, it is true, a crust of tentacles round its mouth. Also its outer germinal layer has certain special modifications. But these are secondary additions, and the inner germinal layer is a simple stratum of cells. On the whole, the *Hydra* has preserved to our day by heredity the simple structure of our primitive organism, the *gastraea* (cf. Chapter XIX.)

In all other animals, particularly the vertebrates, the gastrula is merely a brief transitional stage. Here the two-layer stage of the embryonic development is quickly succeeded by a three-layer, then four-layer, stage. With

appearance of the four superimposed germinal layers we reach again a firm and steady standing-ground, from which we may follow the further, and much more difficult and complicated, course of embryonic development.

SUMMARY OF THE CHIEF DIFFERENCES IN THE OYUM-SEGMENTATION AND GASTRULATION OF ANIMALS.

The animal names are indicated by the letters a-g: a *Leontopis*, b *Amphibia*, c *Mollusca*, d *Elasmobranchia*, e *Arachnida*, f *Insecta*, g *Vertebrata*.

Gastrula without	II. Deepened Segmentation. Amphibians a, b.	
III. Partial Segmentation. Arachnida.	III. Shallow Segmentation. Elasmobranchia c, d.	{ a <i>Cypholophus</i> or cuttle-fish. b <i>Stomatopoda</i> or cuttle-worm.
Gastrula with separate food-yolk. Mollusca.	Shallow gastrula.	{ c <i>Physalia</i> , Salpa, Scyphozoa, Medusa, etc.
	IV. Superficial Segmentation. Insecta a, e, f, g.	{

THE GASTRULATION OF THE VERTEBRATE¹

THE remarkable processes of gastrulation, ovum-segmentation, and formation of germinal layers present a most conspicuous variety. There is to-day only the lowest of the vertebrates, the amphioxus, that exhibits the original form of these processes, or the palingenetic gastrulation which we have considered in the preceding chapter, and which culminates in the formation of the archegastrula (Fig. 38). In all other extant vertebrates these fundamental processes have been more or less modified by adaptation to the conditions of embryonic development (especially by changes in the food-pole). They exhibit various convergent types of the formation of germinal layers. However, the different classes vary considerably from each other. In order to grasp the unity that underlies the various phenomena and

the unity of the "phylogenetic unity," which I developed in my *General Morphology* in 1866, is now generally accepted. All impartial zoologists agree to-day that all the vertebrates, from the lowest to the ape and in fishes

"the primitive vertebrates." Hence the embryonic processes, by which each individual vertebrate is developed, must also be capable of being reduced to one common type of embryonic development; and this primitive type is most certainly exhibited to-day by the amphioxus.

It must, therefore, be our next task to make a comparative study of the various forms of vertebrate gastrulation, and trace them backwards to that of the lancelet. Broadly speaking, they fall first into two groups: the older cyclostomes, the earliest fishes, most of the amphibia, and the viviparous mammals, have heli-

helioic ova—that is to say, ova with total, isotropic segmentation; while the younger cyclostomes, most of the fishes, the cephalopods, reptiles, birds, and monotremes, have meroblastic ova, or ova with partial discoid segmentation. A closer study of these shows, however, that these two groups do not present a natural unity, and that the historical relations between their several divisions are very complicated. In order to understand them properly, we must first consider the various modifications of gastrulation in these classes. We may begin with that of the amphibia.

The most suitable and most available objects of study in this class are the eggs of our indigenous amphibian, the talisman frog and toad, and the tailed salamander. In spring they are to be found in slugs in every pond, and careful examination of

real features of the

In order to understand the whole process rightly and follow the formation of the germinal layers and the gastru-

"A the frog and salamander must be carefully hardened; then the thinnest possible sections must be made of the hardened ova with the microscope, and the thinnest sections must be very closely compared under a powerful microscope.

The ova of the frog or toad are globular in shape, about the twelfth of an inch in diameter, and are clustered in jelly-like masses, which are lumped together in the case of the frog, but form long strings in the case of the toad. When we examine the opaque, grey, brown, or blackish ova closely, we find that the upper half is darker than the lower. The middle of the upper half is in many species black, while the middle of the lower half is white." In this way we get a definite axis of the ova with two poles. To give a clear

¹ Cf. Huxley's *Manual of Comparative Zoology*, vol. 2; Theodor Morgan's *The Development of the Frog's Egg*.

² The colouring of the egg of the amphioxus is caused by the accumulation of dark-coloured matter at the animal pole of the ovum. In consequence of this, the animal cells of the vertebrates are darker than the vegetal cells of the invertebrates. We find the reverse of this in the case of most animals, the protoplasm of the ectodermal cells being usually darker and more granular.

idea of the segmentation of this ovum, it is best to compare it with a globe, on the surface of which are marked the various parallels of longitude and latitude. The superficial dividing lines between the different cells, which come from the repeated segmentation of the ovum, look like deep furrows on the surface, and hence the whole process has been given the name of furcation. In reality, however, this "furcation," which was formerly regarded as a very mysterious process, is

in this position throughout the course of the segmentation, and its cells multiply much more briskly. Hence the cells of the lower hemisphere are found to be larger and less numerous. The cleavage of the stem-cell (Fig. 40 *A*) begins with the formation of a complete furrow, which starts from the north pole and reaches to the south (*B*). An hour later a second furrow starts in the same way, and this cuts the first at a right angle (Fig. 40 *C*). The ovum is thus divided into four equal

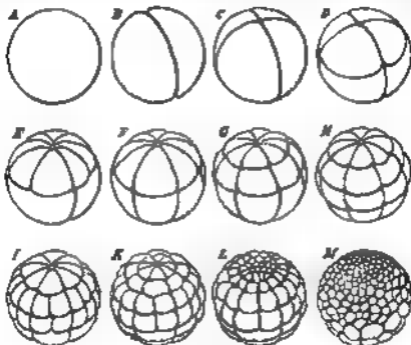


FIG. 40.—The cleavage of the frog's ovum (imagined as a globe). *A* ovum-cell. *B* the first two upper cells. *C* four cells. *D* eight cells (4 normal and 4 vegetative). *E* sixteen cells (12 normal and 4 vegetative). *F* sixteen cells (12 normal and 4 vegetative). *G* twenty-four cells (16 normal and 8 vegetative). *H* thirty-two cells (24 normal and 8 vegetative). *I* thirty-two cells. *J* forty cells. *K* forty cells. *L* forty cells. *M* the cells (4 normal and 36 vegetative).

nothing but the familiar, repeated cell-segmentation. Hence also the segmentation-cells which result from it are equal cells.

The unequal segmentation which we observe in the ovum of the amphibian has the special feature of beginning at the upper and darker pole (the north pole of the terrestrial globe in our illustration), and slowly advancing towards the lower and brighter pole (the south pole). Also the upper and darker hemisphere occupies

parts. Each of these four "vegetative cells" has an upper and darker and lower, brighter half. A few hours later a third furrow appears, vertically to the first two (Fig. 40 *F*). The globular is now composed of eight cells, four above (northern) and four below (southern). Next, each of the four upper cells divides by a cleavage beginning from pole, so that we now have eight above and four below (Fig. 40 *E*). Later, the

four new longitudinal divisions extend gradually to the lower cells, and the number rises from twelve to sixteen (*F*). Then a second circular furrow appears, parallel to the first, and nearer to the north pole, so that we may compare it to the north polar circle. In this way we get twenty-four segmentation-cells—sixteen upper, smaller, and darker ones, and eight smaller and lighter ones below.

In succession forty, forty-eight, fifty-six, and at last sixty-four cells (*I, K*). In the meantime, the two hemispheres differ more and more from each other. Whereas the sluggish lower hemisphere long remains at thirty-two cells, the lively northern hemisphere briskly sub-divides twice, producing first sixty-four and then 128 cells (*L, M*). Thus we reach a stage in which we count on the surface



Fig. 40



Fig. 41



Fig. 43

VIEW OF THE EMBryo IN LONG SECTION

Fig. 44 represents the embryo in long section, with all the structures mentioned in the text. The central cavity is the notochord, the dark outer layer is the ectoderm, the lighter inner layer is the endoderm, and the yellowish layer is the mesoderm. The embryo is shown in a long section, with the central cavity and the surrounding layers. The labels include 'F' for furrow, 'P' for pole, and 'N' for north.

(*G*). Soon, however, the latter also sub-divide into sixteen, a third set "meridian of latitude" appearing, this time in the southern hemisphere: this makes thirty-two cells altogether (*H*). These eight new longitudinal lines are formed at the north pole, and these proceed to divide, first the darker cells above and afterwards the lighter southern cells, and finally reach the south pole. In this way we get

of the same 128 small cells in the upper half and thirty-two large ones in the lower half, or 160 altogether. The dissimilarity of the two halves increases: while the northern breaks up into a great number of small cells, the southern consists of a much smaller number of larger cells. Finally, the dark cells of the upper half grow almost over the surface of the ovum, leaving only a small circular spot

at the south pole, where the large cells of the lower half are visible. This white region at the south pole corresponds, as we shall see afterwards, to the primitive mouth of the gastrula. The

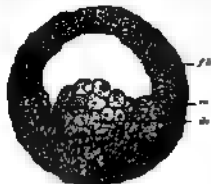


FIG. 41.—Blastula of the water-mole salamander (*Pleurodus*). *fb*, uppermost end; *ec*, cells of the ectoderm; *fb*, future mouth.

..... of the inner and larger and clearer cells (including the white polar region) belongs to the endoderm layer. The outer envelope of dark smaller cells forms the ectoderm or skin-layer.

In the center, a large cavity, full of fluid, has been formed within the globular body—the segmentation-cavity or embryonic cavity (*blastula*, Fig. 41-42 *P*). It extends considerably as the cleavage proceeds, and afterwards assumes an almost semi-circular form (Fig. 43 *P*). The frog-embryo now resembles a small hollow animal half and solid vegetal half.

Now a second, narrower but longer, cavity arises by a process of folding at the lower pole, and by the falling away from each other of the white endodermic cells (Figs. 41-42 *N*). This is the primitive gut-cavity or the gastric cavity of the gastrula, *pharynx* or *archenteron*. It was first observed in the ovum of the amphibian by Rusconi, and so called the Rusconian cavity. The reason of its peculiar narrowness here is that it is, for the most part, full of yolk-cells of the endoderm. These also stop up the whole of the wide opening of the gut-cavity.

and form what is known as the "yolk-stopper," which is seen freely at the white round spot at the south pole (*P*). Around it the endoderm is much thicker, and forms the border of the primitive mouth, the

most important part of the embryo (Fig. 44 *S*, *R*). Soon the primitive gut-cavity stretches further and further at the expense of the segmentation-cavity (*P*), until at last the latter disappears altogether. The two cavities are only separated by a thin partition (Fig. 43 *S*). With the formation of the primitive gut our frog-embryo has reached the *gastrula* stage, though it is clear that this ontogenetic amphibian gastrula is very different from the real paleontologic gastrula we have considered (Figs. 30-36).

In the growth of this hooded gastrula we cannot sharply mark off the various stages which we distinguish successively in the blastula, *gastrula*, *neurula* and *gastrula*. Nevertheless, it is not difficult to reduce the whole ontogenetic or disturbed development of the amphibian gastrula to the true paleontologic formation of the archenteron of the amphioxus.

This reduction becomes easier if, after considering the gastrulation of the tailless amphioxus (frog- and toad), we glance for a moment at that of the tailed amphibia, the salamanders. In some of the latter, that have only recently been carefully studied, and that are physiologically older, the process is much simpler and clearer than in the case with the former and longer known. Our common water salamander (*Triton cristatus*) is a particularly good subject for observation. Its minute yolk is much smaller and it forms a less obscured white blastopore-cavity than in the case of the frog; and its gastrulation has better retained the original paleontologic character. It was first described by Scott and Osborn (1879), and Oscar Hertwig especially made

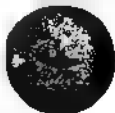


FIG. 42.—Blastula of the water-mole salamander (*Pleurodus*). *fb*, uppermost end; *ec*, cells of the ectoderm; *fb*, future mouth.

vertebrate development. Its globular blastula (Fig. 42) is of loosely-aggregated, yolk-

filled entodermic cells or yolk-cells (*dy*) in the lower vegetal half; the upper, animal half encloses the hemispherical segmentation-cavity (*fh*), the curved roof of which is formed of two or three

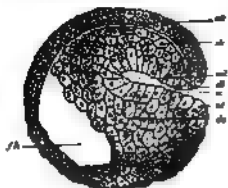


FIG. 21.—Sagittal section of a lamp-brimpy (*Petromyzon*) at the commencement of gastrulation. *fh* shows ventral lobe, at same level as on *fh* segmental cavity, and primitive cell. *dy* shows yolk cells, and curved roof of the mouth, *dy* yolk-cells. (From Herring.)

have the 'border zone'?) The folding which leads to the formation of the gastrula takes place at a spot in the border zone, the primitive mouth (Fig. 46 a).

Unequal segmentation takes place in terms of the cyclotomes and in the older fishes in just the same way as in most of the amphibia. Among the cyclotomes ('round-mouthed') the lamp-brimpy is

halfway between the *sternia* (1

were formerly associated, and 1 than a special class of vertebrate ovum-segmentation in our common lamp-brimpy (*Petromyzon lampretus*) was described by Max Schultze in 1856, and afterwards by Scott (1882) and Goette (1890).

Unequal total segmentation follows the same lines in the oldest fishes, the sculpin and ganoids, which are directly desc. from the cyclotomes. The primitive fish (*Selache*), which is the 'ancestral group of the true fishes,

generally considered, until a short time ago, to be demoblastic. It was not until the beginning of the twentieth century that Rudolph Dain made the important discovery in Japan that one of the oldest living fishes of the shark type (*Cetorhynchus japonicus*) has the same total unequal segmentation as the amphiblastic plated fishes (*ganoids*).¹ This is particularly interesting in connection with our subject, because the few remaining survivors of this division, which was so numerous in palaeozoic times, exhibit three different types of gastrulation. The oldest and most conservative forms of the modern ganoids are the scaly sturgeons (*Sturioidea*), plated fishes of great evolutionary importance, the eggs of which are often as curious; their cleavage is not essentially different from that of the lamprey and the amphibia. On the other hand, the most modern of the plated fishes, the beautifully scaled bony fishes of the North American river (*Lepisosteus*), approaches the osseous fishes, and is decidedly like them. A third genus (*Soma*) fits midway between the sturgeons and the latter.

The group of the lung-fishes (*Dipnoidei* or *Hypos*) is closely connected with the older ganoids. In respect of their whole

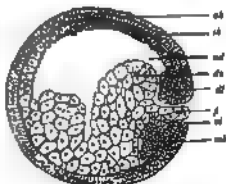


FIG. 22.—Sagittal section of the gastrula of the lamp-brimpy (*Petromyzon*). (From Herring.)

organization they are midway between the gill-breathing fishes and the lung-breathing amphibia, they share with the former the shape of the body and fins with the latter the form of the heart

¹ Rudolph Dain, *Embryonic Cleavage in the Egg of the Shark, Cetorhynchus japonicus*, *Biological Annotaciones*, vol. 22, Tokio, 1910.

and lungs. Of the older types (*Palaeodipnema*) we have now only one specimen, the remarkable *Ceratodus* of East Australia; its amphiblastic gastrulation has been recently explained by Richard Sponson (cf. Chapter XXI.). That of the two

and lachrychia, belong to the old, conservative groups of our stock. Their unequal cross-segmentation and gastrulation have many peculiarities in detail, but can always be replaced with comparative ease to the original cleavage and gastrulation

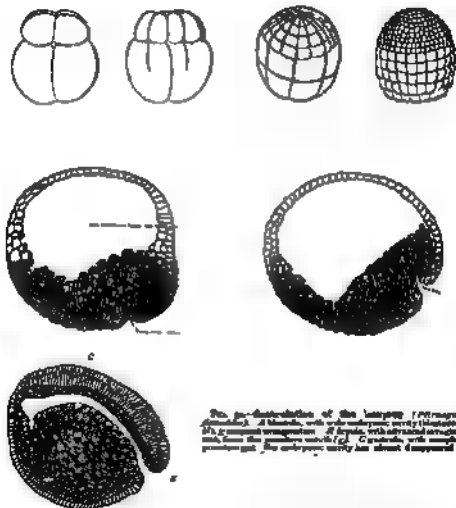


FIG. 51.—Gastrulation of the lamprey (*Petromyzon*). A, Blastula, with wide embryonic cavity (blastocoel). B, Gastrula, with advanced invagination and the embryonic cavity almost disappeared. C, Gastrula, with advanced invagination and the embryonic cavity almost disappeared. D, Gastrula, with advanced invagination and the embryonic cavity almost disappeared. E, Gastrula, with advanced invagination and the embryonic cavity almost disappeared.

America, is not materially different. (CX Fig. 51.)

All these amphiblastic vertebrates, *Petromyzon* and *Ceratodus*, *Acipenser* and *Ceratodus*, and also the teleosts

of the lowest vertebrate, the *Amphioxus*; and this is little removed, as we have seen, from the very simple archegastrula of the *Agathia* and *Monocera* (see Figs. 49-56). All these and many other classes of animals generally agree in the circumstance that in segmentation their

ovum divides into a large number of cells by repeated cleavage. All such ova have been called, after Roux, "whole-cleaving" (*holoblasts*), because their division into cells is complete or total.

In a great many other classes of animals this is not the case, as we find (in the vertebrate stem) among the birds, reptiles, and most of the fishes; among the insects and most of the spiders and

of the ova; this alone divides in segmentation, and produces the numerous cells which make up the embryo. On the other hand, the nutritive yolk is merely a passive part of the contents of the ovum, a subcellular element which contains nutritive material (albumin, fat, etc.), and no participant in a way the development of the developing embryo. The latter takes a quantity of food out of this

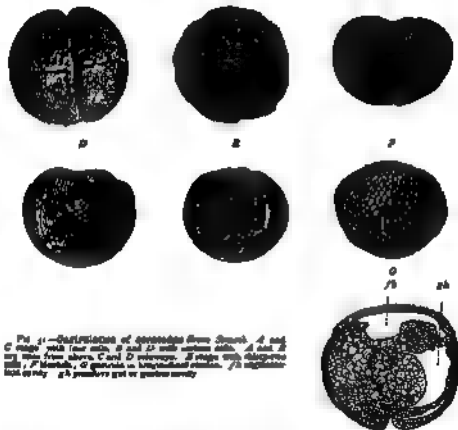


FIG. 1.—Gastrulation of corselets from Stenot. A and C stage with four cells, B and D with sixteen cells. A and B are from above, C and D from below. E stage with thirty-two cells, F gastrula, G gastrula in longitudinal section. a gastrula stage, b gastrula stage.

crabs (of the arthropods); and the cephalopods (of the molluscs). In all these animals the mature ovum, and the stem-cell that arises from it in fertilization, consist of two different and separate parts, which we have called formative yolk and nutritive yolk. The formative yolk alone consists of living protoplasm, and is the active, evolutionary, and nucleated part

of the ovum; this alone divides in segmentation, and produces the numerous cells which make up the embryo. On the other hand, the nutritive yolk is merely a passive part of the contents of the ovum, a subcellular element which contains nutritive material (albumin, fat, etc.), and no participant in a way the development of the developing embryo. The latter takes a quantity of food out of this

THE GASTRULATION OF THE VERTEBRATE

that it was formerly thought the more important of the two. As the respective significance of these two parts of the ovum is often wrongly described, it must be a misleading misleading

real appendage. All cells that have independent nutritious yolk are called,

blast). Their segmentation plate or partial.

There are many difficulties of understanding this part

ring these difficulties, and following the original paligenetic type.



Fig. 10.—Cross of a large egg cell. a, nucleus of the cell; b, nucleolus of the cell; c, nuclear envelope; d, cytoplasm; e, cell membrane; f, cell wall.

comparatively new in the small micro-

found them joined together in lumps of jelly, floating on the surface of the sea, and, as the little cells were completely

in nucleus (b), this is the formative cell of the stem-cell, or the germinal disk all fat-globule (f), and the

cell not dividing at all; -shaped formative cell (b) proceeds quite inde-

like a watch-glass, with thick borders (the upper and) of the nutritive yolk like the

and the border,

tion, or a kind of turning-up of the edge of the blastoderm. In this process the segmentation-plate disappears.

The yolk underneath the blastoderm corresponds to the primitive gut-cavity, and is filled with the overlying food-yolk (a). Thus the formation of the gastrula of our fish is complete. In contrast to the two chief forms of gastrula we considered previously, we give the name of dorsal gastrula (Dorsalgaster, Fig. 34) to this third principal type.

Very similar to the dorsal gastrulation of the frog is that of the lamp or amphioxus, the remarkable cyclostomes that live periodically in the body cavity of fishes, and are distinguished by several notable peculiarities from their nearest

develop like those of the amphioxus, the circular-shaped ones of the lamp are about as much longer, and form a dorsal

anhrane (proctoderm, Fig. 34 c) is and a large, quite clear, and transparent globule of albumin (d). As both poles of

le (which is turned down floating ovum) there is a bi-concave lens composed of protoplasm, and this encloses

chief for entered are determined by the large food-yolk. This takes no direct part in the

city of the gastrulating at the opening. If we imagine the original blastogaster (Figs. 30-34) trying to swallow a

ball of food which is much bigger than itself, it would spread out round it in discoid shape in the attempt, just as we find to be the case here (Fig. 54). Hence we may derive the discoid gastrula from the original ball-gastrula, through the intermediate stage of the hooded gastrula. It has arisen through the accumulation of a store of food-stuff at the vegetal pole, a "nutritive yolk" being thus formed in contrast to the "formative yolk." Nevertheless, the gastrula is formed here, as in the previous cases, by the folding or invagination of the blastula. We can, therefore, reduce this ontogenetic form of the discoid segmentation to the paleontogenic form of the primitive cleavage.

This reduction is tolerably easy and sufficient in the case of the small ova of our deep-sea bony fish, but it becomes

embryonic development and continued by the embryo. This latter develops solely from the living formative yolk of the stem-cell. This is equally true of the ova of our small bony fishes and of the colonial ova of the primitive fishes, reptiles, and birds.

The gastrulation of the primitive fishes or *schizoi* (sharks and rays) has been carefully studied of late years by Ruckert, Rabl, and H. E. Hager in particular, and is very important in the sense that this group is the oldest among living fishes, and their gastrulation can be derived directly from that of the cyclostomes by the accumulation of a large quantity of food-yolk. The oldest sharks (*Cetorhinus*) still have the unequal representation inherited from the cyclostomes. But while in this case, as in the case of



FIG. 55. Gastrulation of a bony fish. A, blastula of the stem-cell (ovum). B, diagram of the gastrula with a large yolk cell. C, diagram of the gastrula with a large yolk cell and a small blastula. (A) of *Chelodactylus*, (B) of *Chelodactylus*, (C) of *Chelodactylus*, a species between the *Chelodactylus* and the *Chelodactylus*, and with a short tail.

difficult and uncertain in the case of the large ova that we find in the majority of the other fishes and in all the reptiles and birds. In these cases the food-yolk is, in the first place, comparatively enormous, the formative yolk being almost negligible beside it; and, in the second place, the food-yolk contains a quantity of different elements, which are known as "yolk-granules, yolk-globules, yolk-plates, yolk-lakes, yolk-vesicles," and so on. Frequently these definite elements in the yolk have been described as real cells, and it has been wrongly stated that a portion of the embryonic body is built up from these cells. This is by no means the case. In every case, however large it is—and even when cell-nuclei travel into it during the cleavage of the border—the nutritive yolk remains a dead accumulation of food, which is taken into the gut during

the gastrulation, the small ovum completely divides into cells on segmentation, this is no longer so in the great majority of the *schizoi* (for *Elozomedonchus*). In these the contractility of the active protoplasm no longer suffices to break up the huge mass of the passive deutoplasm completely into cells; this is only possible in the upper or dorsal part, but not in the lower or ventral section. Hence we find in the primitive fishes a blastula with a small crescentic segmentation-cavity (Fig. 55 B), the wall of which varies greatly in composition. The circular border of the germinal disk which connects the roof and floor of the segmentation-cavity corresponds to the hard-plate at the equator of the amphibian ovum. In the middle of its hinder border we have the beginning of the invagination of the primitive gut

(Fig. 56 sub); it extends gradually from this spot (which corresponds to the blastodermic anus of the amphibia) forward and around, so that the primitive mouth becomes first crescent-shaped and then



FIG. 55.—Blood vessel (Arteriole) of a frog. The vessel is circular, and its lumen is filled with blood. The vessel is surrounded by a layer of connective tissue, and is embedded in the surrounding tissue.

circular, and, as it opens wider, surrounds the half of the larger food-yolk.

Essentially different from the wide-

mouthed is the narrow-mouthed second mouth (or stomodaeum) of the embryo. The reptiles, birds, and even mammals, between the two—as an intermediate stage—we have the amphistoma of the amphibia. The latter has developed from the amphistoma of the gnatostoma and dipneusta, whereas the second mouth (or stomodaeum) has been evolved from the amphibian gastrula by the addition of food-yolk. The change of gastrulation is well found in the remarkable ophidia (*Gyracophora*, *Crotalus*, or *Perotrochus*), serpent-like amphibia that live in moist soil in the tropics, and in many respects represent the transition from the gill-breathing amphibia to the lung-breathing reptiles. Their embryonic development has been explained by the late studies of the brothers Sarasin of *Ichthyophaga* at Ceylon (1887), and those of August Bräuer of the

The bird's egg is particularly important for our purpose, because most of the chief studies of the development of the vertebrates are based on observations of the hen's egg, during

its development, and for this practical and obvious reason very rarely thoroughly investigated. But we can get hen's eggs in any quantity at any time, and, by means of artificial incubation, follow the development of the embryo step by step. The bird's egg differs considerably from the ray mammal ovum in size, a large quantity of food-yolk accumulating within the original yolk or the protoplasm of the ovum. This is the yellow ball which we commonly call the yolk of the egg. In order to understand the bird's egg aright—for it is very often quite wrongly explained—we

shall follow it from the very beginning of its development in the bird's ovary. We then see that the original ovum is a quite small, naked, and simple cell with a nucleus, not differing in either size or shape from the original ovum of the mammals and other animals (cf. Fig. 13 B). As in the case

of the original or primitive ovum (protoplast) we find with a continuous layer of yolk cells. This yolk is the substance, from which the ovum afterwards issues. Immediately underneath it the structureless yolk-membrane is secreted ... of the yolk.

The small primitive ovum of the bird begins very early to take up into itself a quantity of food-stuff through the yolk-membrane, and work it up into the "yellow yolk" in this way the ovum

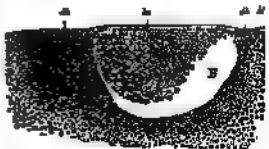


FIG. 56.—Transverse section through the blastula of a bird's egg.

historical and comparative study of those that we can understand the difficult and obscure gastrulation of the amniotes.

appears on the second stage (the morula), which is many times larger than the first, but still only a single embryonic cell. Through the accumulation of the store of yellow yolk within the ball of protoplasm, the nucleus it contains (the germinal vesicle) is forced to the surface of the ball. Here it is surrounded by a small quantity of protoplasm, and with this forms the lens-shaped formative yolk (Fig. 23 B). This is seen on the yellow yolk-ball, at a certain point of the surface, as a small round white spot—the "trend" (*blastodermis*). From this point a thread-like column of white nutritive yolk (A), which contains no yellow yolk-granules, and is softer than the yellow food-yolk, proceeds to the middle of the yellow yolk-ball, and forms there a small central globule of white yolk (Fig. 24 A). The whole of this white yolk is not sharply separated from the yellow yolk, which

(Fig. 25). First two equal segmentation-cells (A) are formed from the ovum. These divide into four (B), then into eight, sixteen (C), thirty-two, sixty-four, and so on. The cleavage of the cells is always preceded by a division of their nuclei. The cleavage surfaces between the segmentation-cells appear at the free surface of the trend as ridges. The first two divisions are vertical to each other, in the form of a cross (B). Then there are two more divisions, which cut the former at an angle of thirty-five degrees. The trend, which thus becomes the germinal disk, now has the appearance of an eight-cupped vase. A circular cleavage next taking place round the middle, the eight triangular cells divide into sixteen, of which eight are in the middle and eight distributed around (C). Afterwards circular disks and radial disks, directed towards the centre, alternate more or less

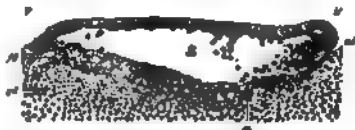


FIG. 24.—Longitudinal section of the interior of a chick (*Proctornis*) at the beginning of gastrulation. (From Huxley.) Shows from the left: A, yolk; B, blastodermis; C, blastodermis; D, blastodermis; E, blastodermis; F, blastodermis.

shows a slight trace of concentric layers in the hard-boiled egg (Fig. 24 C). We also find in the hen's egg, when we break the shell and take out the yolk, a round small white disk at its surface which corresponds to the trend. But this small white "germinal disk" is now further developed, and is really the gastrula of the chick. The body of the chick is formed from it alone. The whole white and yellow yolk-mass is without any significance for the formation of the embryo, it being merely used as food by the developing chick. The clear, glassy mass of albumen that surrounds the yellow yolk of the bird's egg, and also the hard chalky shell, are only formed within the evident round the impregnated ovum.

When the fertilisation of the bird's ovum has taken place within the mother's body, we find in the lens-shaped spot-cell the progress of flat, divided segmentation-

irregularly (A, B). In most of the animals the formation of concentric and radial disks is irregular from the very first; and so also in the hen's egg. But the final outcome of the cleavage-process is once more the formation of a large number of small cells of a similar nature. As in the case of the fish-ovum, these segmentation-cells form a round, lens-shaped disk, which corresponds to the nucleus, and is embedded in a small depression of the white yolk. Between the lens-shaped disk of the morula-cells and the underlying white yolk a small cavity is now formed by the accumulation of fluid, as in the fish-egg. Thus we get the gastrula and not unity recognizable elements of the bird (Fig. 25). The small segmentation-cavity (A) is very flat and much compressed. The upper or dorsal wall (D) is formed of a single layer of cells, distinctly segmented cells; this

corresponds to the upper or animal hemisphere of the triton-blastula (Fig. 43). The lower or ventral wall of the flat dividing space (*bcw*) is made up of larger and darker segmentation-cells; it corresponds to the lower or vegetal hemisphere of the blastula of the water-salamander (Fig. 45 *str*). The nuclei of the yolk-cells, which are in this case especially numerous at the edge of the lens-shaped blastula, travel into the white yolk, increase by cleavage, and contribute even to the further growth of the germinal disk by furnishing it with food-stuff.

The invagination or the folding inwards of the bird-blastula takes place in the

which was described for a long time as the "primitive groove." If we make a vertical section through this part, we see that a flat and broad cleft stretches under the germinal disk forwards from the primitive mouth; this is the primitive gut (Fig. 50 *md*). Its roof or dorsal wall is formed by the folded upper part of the blastula, and the floor or ventral wall by the white yolk (*ord*), in which a number of yolk-nuclei (*ok*) are distributed. There is a brisk multiplication of them at the edge of the germinal disk, especially in the neighbourhood of the sickle-shaped primitive mouth.

We learn from sections through later stages of the second bird-gastrula that

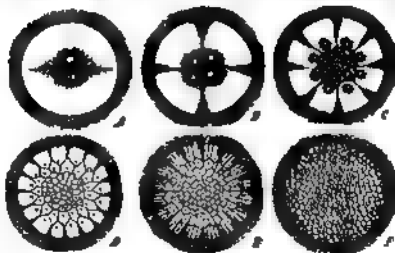


FIG. 51.—Diagrams of cleavage in the chick's ovum, regarded about ten hours. Only the largest yolk cell (*ord*) is shown in them as distinct. A-F, various changes only taken place in them. The much larger egg-yolk, which does not enter in the cleavage, is left out and merely indicated by the dark ring behind.

also also at the hinder pole of the subsequent chief axis, in the middle of the broad border of the round germinal disk (Fig. 59 *z*). At this spot we have the most brisk cleavage of the cells, hence the cells are more numerous and smaller here than in the fore-half of the germinal disk. The border-swelling or thick edge of the disk is less clear but whiter behind, and is more sharply separated from contiguous parts. In the middle of its hind border there is a white, crescent-shaped groove—Koller's sickle-groove (Fig. 59 *z*); a small projecting process in the centre of it is called the sickle-bump (*sk*). This important cleft is the primitive mouth,

the primitive gut-cavity, extending forward from the primitive mouth as a flat pouch, underlining the whole region of the round flat lens-shaped blastula (Fig. 51 *md*). At the same time, the segmentation-cavity gradually disappears altogether, the folded inner germinal layer (*ok*) placing itself from underneath on the overlying outer germinal layer (*sk*). The typical process of invagination, though greatly disguised, can thus be clearly seen in this case, as Goette and Ramber, and more recently Duval (Fig. 61), have shown.

The older embryologists (Pander, Baer, Kowalek), and, in recent times especially,

recently for the birds; and the same has been done for the reptiles by the few studies of Kupffer, Boudin, Westphal, and others. In the shield-shaped germinal disk of the lizard (Fig. 6a), the crocodile, the tortoise, and other reptiles, we find in the middle of the hind border (at the same spot as the sickle groove in the bird) a transverse furrow (σ), which leads into a flat, pouch-like, blind sac, the primitive gut. The fore (dorsal) and hind (ventral) lips of the transverse furrow correspond exactly to the lips of the primitive mouth (or alveo-groove) in the birds.

The gastrulation of the mammalian stem

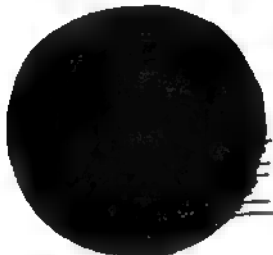


Fig. 6a.—Germinal disk of the lizard (*Lacerta agilis*). (From Kupffer) σ primitive mouth, α sickle, β embryonic disk, γ fore lip, and δ hind gastrulation groove.

is derived from this special embryonic development of the reptiles and birds. This latest and most advanced class of the vertebrates has, as we shall see afterwards, evolved as a comparatively recent date from an older group of reptiles, and all these animals must have come originally from a common stem-form. Hence the distinctive embryonic process of the mammal must have arisen by convergent modifications from the older

gest of the reptiles and birds. Until I admit this thesis we cannot demand the formation of the germinal layers in the mammal, and hence:

I first advanced this fundamental principle in my essay *On the Gastrulation of Mammals* (1877), and sought to show in this way that I assumed a gradual development of the food-yolk and the yolk-sac on the way from the protogila

The convergent process of adaptation, I said, which has occasioned the phy of the rudimentary yolk-sac of the mammal, is perfectly clear. It is due to the fact that the young of the mammal, whose ancestors were certainly oviparous, now remain a long time in the womb. As the great store of food-yolk, which the oviparous ancestors gave to the egg, became superfluous in their descendants owing to the long carrying in the womb, and the maternal blood in the wall of the uterus made itself the chief source of nourishment, the now useless yolk-sac was bound to atrophy by embryonic adaptation.

My opinion, met with little

viduously, attacked by Kolliker, Hensen, and His in particular. However, it has been gradually accepted, and has recently been firmly established by a large number of excellent studies of mammal gastrulation, especially by Edward Van Beneden's studies of the rabbit, but, Solenka's on the marsupials and rodents, Moeske's, and Leberkuhn's on the mole, Kupffer and Kalkoff's on the rodents, Bonnier's on the ruminants, etc. From the general comparative point of view, Carl Rabl in his theory of

the mesoderm, Oscar Hertwig in the latest edition of his *Manual* (1894), and Hubrecht in his *Studies in Mammalian Embryology* (1894), have supported the opinion, and sought to derive the peculiarly modified gastrulation of the mammal from that of the reptile.

In the meantime (1884) the studies of Wilhelm Heacoe and Caldwell provided a proof of the long-suspected and startling fact, that the lowest mammals, the monotremes, lay eggs, like the birds and reptiles, and are not viviparous like the other mammals. Although the gastrulation of the monotremes was not fully known until studied by Richard

Semon in 1894, there was still no little doubt, in view of the great size of their food-yolk, that their ovum-segmentation was discoid, and led to the formation of a sickle-shaped discogastrula, as in the



1. opossum (Didelphis) (from Semon); 2. the four cleavage cells; 3. unsegmented discogastrula.

one of the reptiles and birds. Hence I had, in 1878 (in my essay on *The Gastrula and Ovary-segmentation of Animals*), counted the monotremes among the discoblastic vertebrates. This hypothesis

afterwards by the careful observations of Semon, he gave in the second volume of his great work, *Zoological Journeys in America* (1894), the first description and correct explanation of the discoid gastrulation of the monotremes. The fertilized ovum of the two living monotremes *Salicotea* and *Ornithorhynchus* are balls of oo-cells of an inch in diameter, enclosed in a stiff shell; but they grow considerably during development, so that when laid the egg is three times as large. The structure of the plentiful yolk, and especially the relation of the yellow and the white yolk, are just the same as in the reptiles and birds. As with these, partial cleavage takes place at a spot on the surface at which the small formative yolk and the nucleus it encloses are found. First is formed a lens-shaped circular germinal disk. This is made up of several strata of cells, but it spreads over the yolk-ball, and thus becomes a one-layered blastula. If we then imagine the yolk is continued to be dissolved and replaced by a clear liquid, we have the characteristic blastula of the

higher mammals. In these the gastrulation proceeds in two phases, as Semon rightly observes: firstly, formation of the ectoderm by cleavage at the centre and further growth at the sides; secondly, invagination. In the monotremes more primitive conditions have been retained later than in the reptiles and birds. In the latter, before the commencement of the gastrula-folding, we have, at least at the periphery, a two-layered embryo forming from the cleavage. But in the monotremes the formation of the embryonic ectoderm does not precede the invagination, hence in this case the construction of the germinal layers is less modified than in the other animals.

The marsupials, a second sub-class, come next to the numerous monotremes, the object of the mammals. But as in their case the food-yolk is already absorbed within the mother's body, the partial cleavage has been reconverted into total. One section of the marsupials will show points of agreement with the monotremes, while another section of them, according to the splendid investigations of Selenka, form a connecting-link between them and the placental mammals.

The fertilized ovum of the opossum (*Didelphis*) divides, according to Selenka, into two, then four, then eight equal cells; hence the segmentation is at first



FIG. 6.—Blastula of the opossum (*Didelphis*) (from Selenka): a central pole of the blastula, a single pole on another cell of the ectoderm, or embryonic cells, a group of unsegmented yolk-balls (periphery of the food-yolk), 3. embryonic invagination.

1 or homogeneous. But in the case of the cleavage a larger cell, distinguished by its less clear plasma and its containing more yolk-granules (the mother cell of the ectoderm, Fig. 64), is

larger, clearer, and more transparent than the other. Further, the smaller cell takes a colour in carmine, aniline, etc., more strongly than the larger. By repeated cleavage of it a mantle is formed, and from this a blastula, which changes in a very characteristic way into the greatly modified gastrula. When the number of the segmentation-cells in

one (in the rabbit) about seventy hours after impregnation, the fetus assumes a form very like the archigastrea (Fig. 72). The spherical embryo consists of a central mass of thirty-two soft, rounded cells with dark nuclei, which are flattened into polygonal shape by mutual pressure, and colour dark-brown with osmic acid (Fig. 72 f). This dark central group of cells is surrounded by a lighter spherical membrane, consisting of eight-fold crescent-shaped, small, and five-grained cells which lie close together in a single stratum, and only colour slightly in osmic acid (Fig. 72 c). The authors who regard this embryonic form as the primary gastrula of the placental coelote (the outer layer as the ectoderm and the inner as the endoderm). The endodermic membrane is only interrupted at one spot, one, two, or three of the ectodermic cells being loose there. These form the yolk-stopper, and fill up the mouth of the gastrula (a). The central primitive cavity (d) is full of endodermic cells. The unilaminar type of the mammalian gastrula is accentuated in two ways. However, opinions still differ considerably as to the real nature of this "primitive gastrula" of the placental and its relation to the blastula into which it is converted.

As the gastrulation proceeds a large spherical blastula is formed from the peculiar solid amphigastrea of the blastula, as we saw in the case of the invertebrate. The accumulation of fluid in the solid gastrula (Fig. 72 f) leads to the formation of an eccentric cavity, the group of the darker endodermic cells (b) remaining directly attached at one spot with the round enveloping stratum of the lighter ectodermic cells (c). This spot corresponds to the original primitive mouth (proctoderm or blastopore). From this important spot the inner germinal layer spreads all round on the inner surface of the outer layer, the cell-stratum of which forms the wall of the hollow sphere; the extension proceeds from the vegetal towards the animal pole.

The omegagastic gastrulation of the placental has been greatly modified by secondary adaptation in the various groups of this most advanced and youngest sub-class of the mammalia. Thus, for instance, we find in many of the rodents (guinea-pigs, mice, etc.) apparently a temporary invasion of the two germinal layers. This is due to a so-called "mesodermal wall" by what is called the "girdle," a plug-shaped growth of Reuber's "roof-layer." It is a thin layer of flat epithelial cells, that is freed from the surface of the blastoderm in some of the rodents; it has no more significance in connection with the germinal course of placental gastrulation than the conspicuous departure from



FIG. 72.—Longitudinal section through the early gastrula of the rodent (Fig. 72). (From Vogel.) a, proctoderm; b, endoderm; c, ectoderm; d, primitive gut; e, yolk-stopper; f, central cavity.

globular shape in the blastula of some of the invertebrates. In some pigs and rodents it grows into a thread-like, long and thin tube.

Thus the gastrulation of the placental is modified. In the amphibian, the primitive form is reduced to the original type, the invagination of the modified blastula. Its result is that the folded part of the blastoderm does not form a completely closed (only open at the primitive mouth) blind sac, as in vertebrates; but this blind sac has a wide opening at the ventral curve (opposite to the dorsal mouth); and through this opening the primitive gut communicates from the first with the embryonic cavity of the blastula. The folded crest-shaped

emboderm grows with a fine circular border on the inner surface of the ectoderm towards the vegetal pole; when it has reached this, and the inner surface of the blastula is completely grown over, the primitive gut is closed. This remarkable

their ancestors (the reptiles), is atrophied. This proves the essential unity of gastrulation in all the vertebrates, in spite of the striking differences in the various classes.

In order to complete our consideration of the important processes of gastrulation

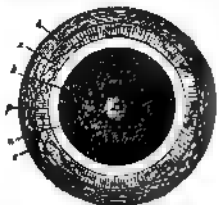


FIG. 91.—Stage-cell of the mammalian egg (from the rabbit). 1, blastoderm, 2, animal ectoderm, 3, pro-
toplasm of the stage-cell, 4, modified zona pellucida, 5, dead space-cell.

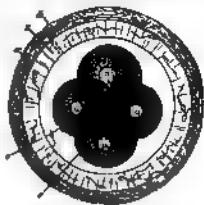


FIG. 92.—The first four segmentation-cells of the rabbit egg. 1, animal ectoderm, 2, dead space-cell, 3, zona pellucida, 4, blastoderm.



FIG. 93.—Indirect cleavage of the mammalian egg (from the rabbit). The stage-cell has divided into two unequal cells, one larger (a) and one smaller (b). 1, animal ectoderm, 2, blastoderm, 3, dead space-cell, 4, zona pellucida, 5, outer blastoderm, 6, inner blastoderm, 7, dead space-cell.

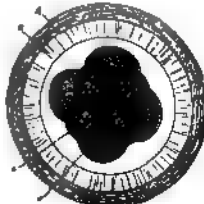


FIG. 94.—Mammalian ovum with eight segmentation-cells (from the rabbit). 1, four lower and higher cells, 2, four smaller and smaller cells, 3, zona pellucida, 4, outer blastoderm, 5, inner blastoderm, 6, dead space-cell.

direct transition of the primitive gut-cavity into the segmentation-cavity is explained simply by the assumption that in most of the mammals the yolk-mass, which is still possessed by the chief forms of the class (the monotremes) and

even now gastrulation, we will, in conclusion, cast a brief glance at the fourth chief type—superficial segmentation. In the vertebrates this form is not found at all. But it plays the chief part in the large class of the arthropods—the insects,

It was also shown that what is called delamination—the rise of the two primary germinal layers by the folding of the surface of the blastoderm (for instance, in the *Geryoneis* and other animals)—was a secondary formation, due to ontogenetic

they attach themselves to the inner wall of the blastula, and form a second internal epithelial layer—that is to say, the entoderm. In these and many other contrivances of modern embryology the first requisite for clear and natural explanation

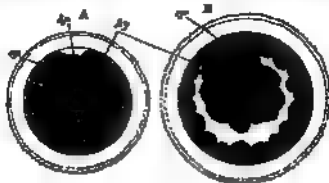


FIG. 55.—Gastrula of the rabbit. A, a mid-ventral cleavage of cells, B changing into the embryo proper, C primitive mouth, D notochord, E blastopore.

variations from the original invagination of the blastula. The same may be said of a fact is called "immigration," to which certain cells or groups of cells are detached from the simple layer of the blastoderm, and travel into the interior of the blastula.

is a careful and discriminative distinction between paleogenetic (hereditary) and ontogenetic (adaptive) processes. If this is properly attended to, we find evidence everywhere of the biogenetic law.

CHAPTER X.

THE COELOM THEORY

THE two "primary germinal layers" which the gastrula theory has shown to be the first foundation in the construction of the body are found in this simplest form throughout life only in animals of the lowest grade—in the gastrulae, or hydra (the stem-form of the sponges), hydroids, and simple animals. In all

the other animals new strata are formed subsequently between these two primary body-layers, and these are generally comprehended under the title of the middle layer, or mesoderm. As a rule, the

various products of this middle layer afterwards constitute the great bulk of the animal frame, while the original entoderm, or internal germinal layer, is restricted to the lining of the alimentary canal and its glandular appendages; and, on the other hand, the ectoderm, or external germinal layer, furnishes the outer clothing of the body, the skin and

in large groups of the lower such as the sponges, corals, and in the middle germinal layer

as a single connected mass, and of the body is developed from it; these have been called the three-layered metazoa, in opposition to the layered animals described.

Like the animals, they have no body-cavity; that is to say, no cavity distinct from the alimentary system. On the other hand,

they have this real body-cavity (*coeloma*), and so are called coelomates; we can distinguish three main layers, which develop from the two primary layers. To the same class belong all true vertebrates (excepting the placental), and also

those evolved from them — molluscs, annelids, arthropods, tunicates, and vertebrates.

multicellular metazoa, is the oldest and most important organ of all the metazoa, and, together with the primitive mouth, is formed in

the gut, it is only at a much later stage that the body-cavity, which is entirely wanting in the coelenterata, is developed out of the metazoa between the body wall. The two cavities are entirely different in content and purpose. The alimentary cavity (*coeloma*) serves the purpose of digestion; it contains water and food taken from without, as well as the pulp (*chymus*) formed from

the body-cavity, quite distinct from the gut and closed externally, has nothing to do with digestion; it encloses the gut

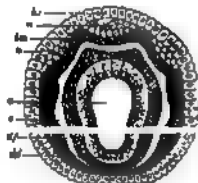


Fig. 74

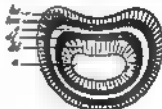


Fig. 75

Fig. 74 and 75—Diagram of the five secondary germinal layers, showing the body wall (la) and the gut wall (ld) with various internal structures labeled. The diagram shows the body wall (la) and the gut wall (ld) with various internal structures labeled. The diagram shows the body wall (la) and the gut wall (ld) with various internal structures labeled.

The body-cavity (*coeloma*) is therefore a new acquisition of the animal body, much younger than the alimentary system, and of great importance. I first pointed out this fundamental significance of the coelom in my *Monograph on the Spinger* (1872), in the section which shows a distinction between the body-cavity and the gut-cavity, and which follows immediately on the germ-layer theory and the ancestral tree of the animal kingdom (the first sketch of the germ-layer theory). Up to that time these two principal cavities of the animal body had been confused, or very imperfectly distinguished; chiefly because Leuckart, the founder of the coelenterata group (1848), has attributed a body-cavity, but not a gut-cavity, to these lowest metazoa. In reality, the truth is just the other way about.

Itself and its glandular appendages, and also contains the actual products and a certain amount of blood or lymph, a fluid that is transported through the ventral wall.

As soon as the body-cavity appears, the ventral wall is found to be separated from the outer body-wall, but the two continue to be directly connected at various points. We can also then always distinguish a number of different layers of tissue in both walls—at least two in each. These three-layers are formed originally from four different simple cell-layers, which are the mesodermis and four secondary germinal layers. The outermost of these, the ectodermis-layer (Fig. 74, 75 la), and the innermost, the gut-gland-layer (ld), remain at first simple epithelia or covering-layers. The one covers the outer

surface of the ventral wall; hence they are called *confining* or *limiting* layers. Between them are the two middle-layers, *soblasts*, which enclose the body-cavity.



Fig. 25.—Coelomata of *Ascaris*, showing the body-cavity.

in permanent form.

The four secondary germinal layers are so distributed in the structure of the body in all the coelomata for all animals that have a body-cavity that the outer two, joined fast together, constitute the body-wall, and the inner two the ventral wall. Each of the walls is a *limiting* layer.

tissues, and glands and nerves, middle layers form. The great bulk of the fibrous tissue, muscle, and connective matter. Hence the latter have been called fibrous or muscular layers. The outer middle layer, which lies on the inner side of the skin-soblast-layer, is the skin fibre-layer, the inner middle layer, which attaches from without to the ventral glandular layer, is the ventral fibre layer. The former is usually called briefly the parietal, and the latter the visceral layer or mesoderm. Of the many different names that have been given to the four secondary germinal layers, the following are the most common:

- | | | |
|--------------------------------------|---------------------------------|--|
| 1. Skin-layer (outer limiting layer) | II. Parietal layer (epithelial) | 3. Epithelial layer (inner limiting layer) |
| 4. Skin-layer (outer limiting layer) | II. Parietal layer (epithelial) | 3. Epithelial layer (inner limiting layer) |
| 4. Gut-layer (inner limiting layer) | II. Parietal layer (epithelial) | 3. Epithelial layer (inner limiting layer) |

The first scientist to recognise and clearly distinguish the four secondary germinal layers was Baer. It is true he was not quite clear as to their origin and further.

Several mistakes in detail in explaining them. But, on the whole, their great importance did not escape him. However, in later years his view had to be given up in consequence of more accurate observations. Remak then propounded a three-layer theory, which was generally accepted. These theories of cleavage, however, began to give way thirty years when Kowalevsky (1871) showed in the case of *Ascaris* (a very clear typical subject of gastrulation) the middle germinal layer and the two outer layers arise not by cleavage, but by folding—by a secondary invagination of the primary inner germ-layer. This invagination or folding proceeds from the posterior mouth, at the two sides of which (right and left) a couple of pouches are formed. As these out-pouches or pouches detach themselves from the permanent gut, a double body-cavity is formed (Page 74-6).

This same kind of coelom-formation in *Ascaris* was afterwards found by Kowalevsky in *Ascaris*.

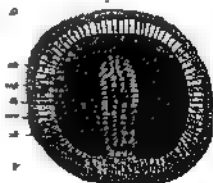


Fig. 27.—Coelomata of *Ascaris*, in section. (From Kowalevsky.) D dorsal side, V ventral side of outer germinal layer, W ventral wall, B body-cavity, G gut, P parietal wall, M middle germinal layer.

In zoology—E. Ray-Lankester and F. Huxley. On the strength of these and other studies, as well as most extensive research of their own, the brothers Oscar and Richard Hertwig constructed in 1881

the Cilom Theory. In order to appreciate fully the great merit of this illuminating and helpful theory, one must remember what a chaos of contradictory views was then represented by the "problem of the mesoderm," or the much-disputed "question of the origin of the middle germinal layer." The cilom theory brought some light and order into this infinite confusion by establishing the following points: 1. The body-cavity originates in the great majority of animals (especially in all the vertebrates) in the same way as in insects: a couple of pinches or sacs are formed by folding inward at the primitive mouth, between the two primary germinal layers; as these pinches detach from the primitive gut, a pair of outpocketings (right and left) are formed, the continuations of these produce middle body-cavity. A. B.

outer-embryonic development, not as a pair of hollow pinches, but as solid layers of cells (in the shape of a pair of mesodermal strands)—as happens in the higher vertebrates—we have a secondary (homologous) modification of the primary (heterologous) structure, the two walls of the pouches, inner and outer, have been pressed together by the expansion of the large fluid yolk. 3. Hence the strands from the first of the germinally distinct layers, which do not separate by the shrinkage of a primary embryo middle layer (as Huxley supposed). 4. These two middle layers have, in all vertebrates, and the great majority of the invertebrates, the same radical significance for the construction of the animal body: the inner middle layer, or the visceral mesoderm, (gut-fibre layer), attaches itself to the original ectoderm, and forms the fibrous, muscular, and connective part of the visceral wall, the outer middle layer, or the parietal mesoderm, (skin-fibre layer), attaches itself to the original ectoderm, and forms the fibrous, muscular, and connective part of the body-wall. 5. It is only at the point of origination, the primitive mouth and its vicinity, that the four secondary germinal layers are directly connected; from this point the two middle layers advance forward separately between the two primary germinal layers, to which they eventually attach themselves. 6. The further separation or differentiation of the four secondary germinal layers and their division into the various tissues and organs takes place especially in the later fore-part or head of the embryo, and

extend backwards from there towards the primitive mouth.

All animals in which the body-cavity demonstrably arises in this way from the primitive gut (vertebrates, tunicates, echinoderms, arthropods, and a part of the molluscs) were comprised by the Haeckels under the title of *mesodermia*, and were contrasted with the other groups of the *parietodermia* (with false body-cavity) and the *ectodermia* (with no body-cavity). However, this radical distinction and the views as to classification which it occasioned have been shown to be untenable. Further, the absolute differences in transformation which the Haeckels set up between the *mesodermia* and *parietodermia* cannot be sustained.

For these and other reasons their paleontology has been much criticised and partly



FIG. 1.—Section of a young embryo. (From Haeckel.) The central cavity, or gut, is surrounded by two layers, the ectoderm and endoderm, and the space between them is the mesoderm. The ectoderm and endoderm are the primary germinal layers, and the mesoderm is the secondary germinal layer.

abandoned. Nevertheless, it has rendered a great and lasting service in the solution of the difficult problem of the mesoderm, and a central part of it will certainly be retained. I consider it an especial merit of the theory that it has established the identity of the development of the two middle layers in all the vertebrates, and has traced them to no ontogenetic modifications back to the original piling-up of the development that we still find in the cephalopods. Carl Rabl comes to the same conclusion in his able *Theory of the Mesoderm*, and so do Ray-Lankester, Ruedor, Kappeler, Ruckert, Schmidt, Hatachek, and others. There is a general agreement in them and many other recent writers that all the different forms of cilom-construction, like those of gastrulation, follow one and the same strict homodynamic law in the next vertebrate stem; in spite of their apparent differences, they

are all only coelogenetic modifications of one pelagogenetic type, and this original type has been preserved for us down to the present day by the invaluable amphioxus.

But before we go into the regular conformation of the amphioxus, we will glance at that of the arrow-worm (*Sagitta*), a remarkable deep-sea worm that is interesting in many ways for comparative anatomy and ontogeny. On the one hand, the transparency of the body of the embryo, and, on the other hand, the typical simplicity of its embryonic development, make the sagitta a most instructive object in connection with various problems. The class of the *Chordata*, which is only represented by the cognate genera of *Sagitta* and *Spadella*, is in another respect

afterwards arms). The two sacs are at first separated by a couple of folds of the ectoderm (Fig. 76 *pe*), and are still connected with the primitive gut by wide apertures; they also communicate for a short time with the dorsal side (Fig. 77 *d*). Soon, however, the coelom-pouches completely separate from each other and from the primitive gut, at the same time they enlarge so much that they close round the primitive gut (Fig. 78). But in the middle line of the dorsal and ventral sides the pouches remain separated, thus approaching walls joining here to form a thin vertical partition, the mesentery (*am* and *vm*). Thus *Sagitta* has throughout life a double body-cavity (Fig. 78 *bc*), and the gut is divided to the body-wall both above and below by a mesentery—below



FIG. 76.



FIG. 77.

FIG. 76 and 77.—Transverse section of sagittula-larva. (From Huxley.) FIG. 76 is the transverse section of a sagittula-larva (with chorion removed). FIG. 77 is at the same stage, with chorion removed. *ap*, apical plate; *ep*, ectoderm; *ch*, chorion; *am*, amnion; *gut*, gut.

also a most remarkable branch of the *Elasipoda* vermiform worm. It was therefore very gratifying that Oscar Hertwig (1884) fully explained the anatomy, characteristics, and evolution of the chordata in his careful monograph.

The spherical blastula that arises from the impregnated ovum of the sagitta is converted by a folding at one pole into a typical archigastrea, entirely similar to that of the *Amoeba* which I described (Chapter VIII., Fig. 29). This oval, non-axial-cup-larva (circular in section) becomes bilateral (or tri-axial) by the growth of a couple of coelom-pouches from the primitive gut (Figs. 76, 77). To the right and

shaped fold appears towards the top pole (where the permanent mouth, or,

by the ventral mesentery (*vm*), and above by the dorsal mesentery (*am*). The outer layer of the two coelom-pouches (*ep*) attaches itself to the ectoderm (*ep*), and forms with it the outer body-wall. Thus we have in *Sagitta* a perfectly clear and simple illustration of the original conformation of the enterocoel. This pelagogenetic fact is the more important, as the greater part of the two body-cavities in *Sagitta* changes afterwards into renal glands—the fore or female part into a pair of ovaries, and the hind or male part into a pair of testicles.

Collocated takes place with equal clearance and transparency in the case of

the amphioxus, the lowest vertebrate, and its nearest relatives, the lower teleostei, lampreys, the sea-squirts. However, in these two stems, which we class together as *Chordata*, this important process is more complex, as two other processes are associated with it—the development of the chorda from the notoderm and the separation of the medullary plate or notochord from the ectoderm. Here again the skullian amphioxus has preserved to our own time by tenacious heredity the

while it has been more or less modified by embryonic adaptation in all the other vertebrates (with skulls). Hence we must once more thoroughly understand the paleogenetic embryonic history of the lancelet before we go on to consider the ontogenetic forms of the chorda.

borders of the concave medullary plate fold towards each other and grow underneath the horny-plate, a cylindrical tube is formed, the medullary tube (Fig. 82 a); this quickly detaches itself altogether from the horny-plate. At each side of the medullary tube, between it and the elementary tube (Figs. 79-82 ab), the two parallel longitudinal folds grow out of the dorsal wall of the elementary tube, and form the two coelom-pouches (Figs. 80 and 81 ab). This part of the ectoderm,

of the middle germinal layer, is shown darker than the rest of the inner germinal layer in Figs. 79-82. The edges of the folds meet, and thus form closed tubes (Fig. 82 as median).

During this interesting process the outline of a third very important organ,



FIG. 81.



FIG. 82.

FIGS. 81 AND 82.—TRANSVERSE SECTION OF AMPHIOXUS EMBRYO. FIG. 81 is the stage with two coelom-pouches at the stage with closed median. (From Haeckel.) ab dorsal germinal layer, not medullary plate, not coelom, 10 inner germinal layer, 11 notoderm, 12 coelom-pouch, 13 middle germinal layer, 14 notoderm, 15 dorsal wall of notoderm.

The evolution of the amphioxus, which was first observed by Konstantinov in 1867, has been very carefully studied since by Haeckel (1881). According to him, there are first formed on the lateral gastrula we have already considered (Figs. 36, 37) three parallel longitudinal folds—one single ectodermal fold on the central line of the dorsal surface, and a pair of ectodermal folds at the two sides of the former. The broad ectodermal fold that first appears in the middle line of the flattened dorsal surface, and forms a shallow longitudinal groove, is the beginning of the central nervous system, the medullary tube. Thus the primary outer germinal layer divides into two parts, the middle medullary plate (Fig. 81 ap) and the horny-plate (ab), the beginning of the outer skin or epidermis. At the parallel

the chorda or axial rod, is being formed between the two coelom-pouches. This first condensation of the notoderm, a solid cylindrical cartilaginous rod, is formed in the middle line of the dorsal primitive gut-wall, from the ectodermal cell-streak that runs on here between the two coelom-pouches (Figs. 79-82 cd). The chorda appears at first in the shape of a flat longitudinal fold or a shallow groove (Figs. 80, 81); it does not become a solid cylindrical rod until after separation from the primitive gut (Fig. 82). Hence we might say that the dorsal wall of the primitive gut forms three parallel longitudinal folds at this important period—one single fold and a pair of folds. The single middle fold becomes the chorda, and the immediately below the groove of the ectoderm, which becomes the medullary

tube; the pair of folds on the right and left lie at the sides between the former and the latter, and form the coelom-pouches. The part of the primitive gut that remains after the cutting off of these three dorsal primitive organs is the post-

(Figs. 23, 24, in the third period of development according to Hatachek). (Strode and Minnie give the name of *chordula* or *chordula* to young fish larvae.) I ascribe the utmost phylogenetic significance to it, as it is found in all the chorda-



Figs. 23 and 24.—Cephalopod of the cephalopod. Fig. 23 shows longitudinal section from the left. Fig. 24 shows transverse section. (From Hatachek.) In Fig. 24 the cephalopod is shown in order to show the division into parts. Fig. 24 is a rather disorganized. a cephalopod, b cephalopod, c cephalopod, d cephalopod, e cephalopod, f cephalopod, g cephalopod, h cephalopod, i cephalopod, j cephalopod, k cephalopod, l cephalopod, m cephalopod, n cephalopod, o cephalopod, p cephalopod, q cephalopod, r cephalopod, s cephalopod, t cephalopod, u cephalopod.



Figs. 25 and 26.—Cephalopod of the cephalopod. Fig. 25 shows longitudinal section from the left. Fig. 26 shows transverse section (slightly disorganized). Labeled as in Figs. 23 and 24.

manent gut; its anterior is the gut-gland-layer or enteric layer.

I give the name of *chordula* or *chordula* to the embryonic stage of the vertebrate organism which is represented by the cephalopod-like form of this period

namely (cephalopod as well as vertebrates) as essentially the same form. Although the metamorphosis of food-yolk greatly modifies the form of the chordula in the higher vertebrates, it remains the same in its main features throughout. In all

folding). These ontogenetic facts are of the greatest importance for the postulated bearing those ancestral forms of the vertebrates which we have to seek in the group of the unarticulated vermians. The coelom-pouches were originally ventral glands in these ancient chordates.

From the evolutionary point of view the coelom-pouches are, in any case, older than the chorda; since they have developed

in the same way as in the chordates in a number of Invertebrates which have no chorda (for instance, *Segella*, Figs 76-78). Moreover, in the amphioxus the first outflow of the coelom appears later than that of the coelom-pouch. Hence we must, according to the biogenetic law, postulate a special intermediate form between the *Gastrea* and the chordula, which we will

call *coelocula*, an unarticulated, worm-like body with primitive gut, primitive mouth, and a double body-cavity, but no chorda. This embryonic form, the *Indoparacelocula* (Fig. 81), may in turn be regarded as the ontogenetic reproduction (inhibited by heredity) of an ancient ancestral form of the coelocula, the *Celocula* (cf. Chapter XX).

In *Segella* and other worm-like animals the mesoderm-pouches (presumably gonads or nephridia) are separated by a complete median partition, the dorsal and ventral mesentery (Fig. 76 dm and vm), but in the vertebrates only the upper part of this vertical partition is maintained, and forms the dorsal mesentery. This mesentery afterwards takes the form of a thin membrane, which fastens the ventral tube to the chorda (for the ventral coelom). At the lower end of the ventral tube the coelom-pouches blend together, thus once or more times breaking down and disappearing. The body-cavity then forms a single simple hollow, in which the gut is quite free, or only attached to the dorsal wall by means of the mesentery.

The development of the body-cavity and the formation of the chordula in the higher vertebrates is, like that of the *Gastrea*, chiefly modified by the pressure of the food-yolk on the embryonic structures, which forces its bladder part into

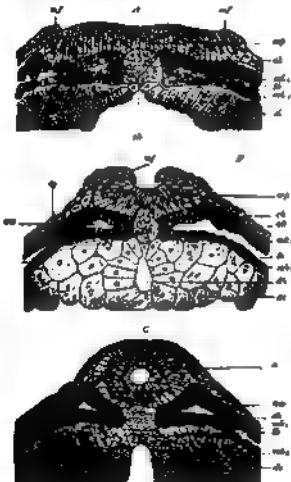


FIG. 81. A, B, C—Vertical section of the dorsal part of chord embryo. (From Hering.) In Fig. A the ventral and dorsal parts of the parietal border of the coelomic blastopore are seen; in Fig. B they grow towards each other, in Fig. C they meet and form the ventral tube. dm, ventral mesentery; vm, ventral mesentery; ch, chordula; co, coelom; dm, dorsal mesentery; vm, ventral mesentery; ch, chordula; co, coelom; dm, dorsal mesentery; vm, ventral mesentery; ch, chordula; co, coelom.

a discoid expansion. These convergent modifications seem to be so great that until twenty years ago these important processes were totally misunderstood. It was generally believed that the body-cavity in man and the higher vertebrates was due to the division of a simple middle layer, and that the latter arose by cleavage from one or both of the primary germinal layers. The truth was brought to light at last by the comparative embryological research of the Hertwigs. They showed in their *Culom Theory* (1881) that all vertebrates are true coelomates, and that in every case a pair of coelom-pouches are developed from the primitive gut by folding. The convergent channels-forms of the cranial region therefore to be derived from the pluri-genetic embryology of the amphioxus in the same way as I had previously proved for their vertebrate forms.

The chief difference between the evolution of the ascidia (*amphioxus*) and the other vertebrate with skull-formation is that the two coelom-folds of the primitive gut in the former are from the free hollow vesicles, filled with fluid, but in the latter are coelom-pouches, the layers of which (inner and outer) close with each other. In certain portions we still find a pouch or pocket by their nature, whether it is full or empty. It is different in *amphioxus*. In some of our embryological lower vertebrate forms does not come for very much. In many of the mammals and large mammals on this subject it is proved that vesicles, pouches, or was almost that name only when they are inflated and filled with a clear fluid. When they are not so filled (for instance, when the primitive gut of the gastrula is filled with yolk, or when the walls of the empty coelom-pouches are pressed together), these vesicles must not be considered any longer, but "solid structures."

The accumulation of body-yolk in the ventral wall of the primitive gut (Figs 85, 86) is the simple cause that converts the Y-shaped coelom-pouches of the ascidian into the U-shaped coelom-structures of the vertebrate. To convince ourselves of this we need only compare, with Hertwig, the pluri-genetic coelomata of the amphioxus (Figs. 80, 81) with the corresponding convergent form of the amphibia (Figs. 89-90), and construct the simple diagram that connects the two (Figs. 87, 88). If we

imagine the ventral half of the primitive gut-wall in the amphioxus embryo (Figs. 77-84) dissected with local-yolk, the vesicular coelom-pouches (B) must be pressed together by this, and forced to conform to the shape of a U. In double space between the gut-wall and body-wall (Figs. 86, 87). This expansion follows a downward and forward direction. They are not directly connected with these two walls. The real unbroken connection between the two middle layers and the primary germ-layers is found right at the back, in the region of the primitive mouth (Fig. 87, 4). At this important spot we have the source of embryonic development (*blastopore*), or "zone of growth," from which the coelomation (and also the gastrulation) originally proceeds. Hereby even circumscribed in turning, in the coelomata-embryo of the water salamander (*Triton*), between the first structures of the two middle layers, the role of



FIG. 88.—Transverse section of the amphioxus-embryo of a bird from a large egg at the close of the first day of development. (From Hertwig.) A horizontal (ventral) or posterior line. B) dorsal side of same. C) embryonic folds. At dorsal end within lower part of the body layer smaller end of the main-coelomata, at lateral (body) part of same, or lateral pouch, short structure of the body-div. of coelomata-embryo.

the body-cavity, which is represented in the diagrammatic transverse form (Figs. 87, 88). In sections both through the primitive mouth stage (Fig. 89) and in form of it (Fig. 90) the two middle layers (a) and (b) diverge from each other, and divide the two body-cavities as narrow chinks. At the primitive mouth itself (Fig. 90 a) we can penetrate into them from without. It is only here at the border of the primitive mouth that we can show the direct transition of the two middle layers into the two folding layers or primary germinal layers.

The structure of the chorda also shows the same features in these coelomata-embryos of the amphibia (Fig. 91) as in the amphioxus (Figs. 79, 80). It arises from the ectodermic cell-trunk, which forms the middle dorsal line of the primitive gut, and occupies the space between the two coelom-pouches (Fig. 91 d).

While the nervous centre is formed here in the middle line of the back and separated from the ectoderm as "modulatory tube," there takes place at the same time, directly underneath, the accumulation of the coelom from the ectoderm (Fig. 92 A, B, C). Under the chorion is formed (out of the ventral ectoderm half of the gastrula) the permanent gut or visceral cavity (*enteron*) (Fig. 92 B, A). This is done by the confluence, under the chorion in the median line, of the two dorsal side-borders of the gut-gland-layer (*sk*), which were previously separated by the chorda-plate (Fig. 91 A, sk); these now alone form the clothing of the visceral cavity (*sk*) (enteroderm, Fig. 92 C). All these important modifications take place at first in the fore or head-part of the embryo, and spread backwards from there; here at the head end, the region of the primitive mouth, the important border of the mouth for *propharynx*,

possible as a matter of fact; even the older illustrations showed an essential identity of features. Thus forty years ago Kölliker gave, in the first edition of his *Human Embryology* (1861), some sections of the chicken-embryo, the features of which could at once be reduced to those already described and explained in the sense of Haeckel's coelom-theory. A section through the embryo in the hatched hen's egg towards the close of the first day of incubation shows in the middle of the dorsal surface a broad ectodermic modulatory groove (Fig. 92 B f), and underneath the middle of the chorion (*ch*) and on each side of it a couple of broad mesodermic layers (*sp*). These enclose a narrow space or cleft (*vak*), which is nothing else than the structure of the body-cavity. The two layers that enclose it—the upper parietal layer (*sp*) and the lower visceral layer (*sk*)—are pressed together from without, but clearly distin-



Fig. 92.—Transverse section of the vertebrate-embryo of a hen's egg on the second day of incubation. (*From Kölliker*) A, *ectoderm*, or modulatory tube, at dorsal, and primitive propharynx; B, *propharynx*, or modulatory tube, at ventral, and primitive propharynx; C, *ectoderm*, or modulatory tube, at dorsal, and primitive propharynx; D, *propharynx*, or modulatory tube, at ventral, and primitive propharynx; E, *propharynx*, or modulatory tube, at ventral, and primitive propharynx; F, *propharynx*, or modulatory tube, at ventral, and primitive propharynx.

remains for a long time the source of development or the zone of fresh construction, is the further building-up of the organism. One has only to compare carefully the illustrations given (Figs. 95-97) to see that, as a fact, the coelomic coloration of the amphibia can be deduced directly from the phylogenetic form of the nemata (Figs. 79-80).

The same principle holds good for the annelids, the reptiles, birds, and mammals, although in this case the processes of coloration are more modified and more difficult to identify as sources of the colossal accumulation of food-yolk and the corresponding notable fattening of the germinal disk. However, as the whole group of the annelids has been developed at a comparatively late date from the class of the amphibia, their coloration must also be directly accessible to that of the latter. This is really

guaranteed. This is even clearer a little later, when the modulatory furrow is closed into the nerve-tube (Fig. 93 m).

Special importance attaches to the fact that here again the four secondary germinal layers are already sharply distinct, and easily separated from each other. There is only one very contracted area in which they are connected, and actually pass into each other; this is the region of the primitive mouth, which is contracted in the annelids into a dorsal longitudinal cleft, the primitive groove. Its two lateral lip-borders form the *primitive streak*, which has long been recognized as the most important embryonic source and starting-point of further processes. Sections through this primitive streak (Figs. 94 and 95) show that the two primary germinal layers grow at an early stage (in the striped gastrula of the chick, a few hours after fertilization) into the primitive

most important embryonic processes. From this primary model of construction we can ontogenetically deduce all the embryonic forms of the other vertebrates, the craniota, by secondary modifications. My thesis of the universal formation of the gastrula by folding of the blastula has now been clearly proved for all the vertebrates; so also has been Huxley's thesis of the origin of the middle germinal layer by the folding of a couple of ectoderm-pockets which appear at the border of

typical, unarticulated, worm-like larva, which has an axial chorda between the dorsal nerve-tube and the ventral gut-tube. This instructive chordula (Figs. 83-86) provides a valuable support of our phylogeny; it indicates the important moment in our stem-history at which the stem of the chordonia (tunicates and vertebrates) parted far ever from the divergent stems of the other metazoa (artemisiates, arthropods, and molluscs).

I very earnestly trust my opinion, in the



Fig. 45.—Transverse section of the primitive mouth of a rabbit. (From *The Chordula*). *pr* primitive mouth, *ad* dorsal nerve-tube, *al* axial layer, *ab* axial band, *st* stomodaeum.



Fig. 47.—Transverse section of the primitive mouth of a rabbit. (From *The Chordula*). *pr* primitive mouth, *ad* dorsal nerve-tube, *al* axial layer, *ab* axial band, *st* stomodaeum.

the primitive mouth. Just as the gastrula-theory explains the origin and identity of the two primary layers, so the chordula-theory explains those of the four secondary layers. The point of origin is always the properistoma, the border of the original primitive mouth of the gastrula, at which the two primary layers pass directly into each other.

Moreover, the chordula is important as the immediate source of the chorda, the embryonic reproduction of the ancient,

form of a chordula-theory, that the characteristic chordula-larva of the chordonia has in reality this great significance—it is the typical reproduction (preserved by heredity) of the ancient common ancestor of all the vertebrates and tunicates, the long-extinct *Chordula*. We will return in the twentieth chapter to these worm-like ancestors, which stand out as luminous points in the obscure stem-history of the vertebrate ancestry of our race.

CHAPTER XL

THE VERTEBRATE CHARACTER OF MAN

We have now secured a number of firm standing-places in the labyrinthine course of our individual development by our study of the important embryonic forms which we have called the *zygote*, *morula*, *blastula*, *gastrula*, *ectodermula*, and *chordula*. But we have still in front of us the difficult task of turning the complicated forms of the human body, with all its different parts, organs, members, etc., from the simple form of the *chordula*. We have previously considered the origin of this four-layered embryonic form from the two-layered *gastrula*. The two primary germinal layers, which form the entire body of the *gastrula*, and the two middle layers of the *ectodermula* that develop between them, are the four simple cell-layers, or *epithelia*, which alone go to the formation of the complex body of man and the higher animals. It is no difficult undertaking this construction that we will first seek a companion who may help us out of many difficulties.

This helpful associate is the science of comparative anatomy. Its task is, by comparing the fully-developed bodily form in the various groups of animals, to learn the general lines of organization according to which the body is constructed, as the nature fits it best to determine the affinities of the various groups by critical appreciation of the degrees of difference between them. Formerly, this work was conceived in a teleological sense, and it was sought to find traces of the plan of the Creator in the actual purposeful organization of animals. But comparative anatomy has gone much deeper since the establishment of the theory of descent; its philosophical aim now is to explain the variety of organic forms by adaptation, and their similarity by heredity. At the same time, it has to recognize in the shades of difference in form the degree of blood-relationship, and make an effort to construct the ancestral tree of the animal world. In this way, comparative anatomy unites into the closest relations with comparative

embryology on the one hand, and with the science of classification on the other.

Now, when we ask what position man occupies among the other organisms according to the latest teaching of comparative anatomy and classification, and how man's place in the zoological system is determined by comparison of the present bodily form, we get a very definite and significant reply, and this reply gives us extremely important conclusions that enable us to understand the embryonic development and its evolutionary purpose. Since Cuvier and Lamarck, since the immense progress that was effected in the early decades of the nineteenth century by these two great zoologists, the opinion has generally prevailed that the whole animal kingdom may be distributed in a small number of great divisions or types. They are called types because a certain typical or characteristic structure is continually preserved within each of these large divisions. Since we applied the theory of descent to this doctrine of types, we have learned that this common type is an outcome of heredity; all the animals of one type are blood-relatives, or members of one stem, and can be traced to a common ancestral form. Cuvier and Lamarck set up four of these types: the *vertebrates*, *articulata*, *molluscs*, and *radiata*. The first three of these are still retained, and may be conceived as natural phylogenetic units, as stems or *phyla* in the sense of the theory of descent. It is quite otherwise with the fourth type—the *radiata*. These animals, hitherto known as yet at the beginning of the nineteenth century, were made to form a sort of lumber-room, into which were put all the lower organisms that did not belong to the other three types. As we obtained a closer acquaintance with them in the course of the last sixty years, it was found that we must distinguish among them from four to eight different types. In this way the total number of animal stems or *phyla* has been raised to eight or twelve (cf. Chapter XX.).

There twelve stages of the animal kingdom are, however, by no means continuous and independent types, but have definite relations, partly of subordination, to each other, and a very different phylogenetic meaning. Hence they must not be arranged simply in a row one after the other, as was generally done until thirty years ago, and as still some do now undertake. We must distribute them in their subordination principal groups of very different value, and arrange the various stages phylogenetically on the principles which I laid down in my *Leitfaden* on the *Kämpfer*, and developed in the *Study of the Evolution Theory*. We have first to distinguish the *amorphous animals* (*protists*) from the *multicellular* (*metazoa*) (*metazoa*). Only the latter include the important presence of organization and individuality, and they alone have a primitive cell, and some germinal layer, and tissue.

The *metazoa*, the *multicellular* or *organized*, then sub-divide into two main sections, according as a body cavity is or is not developed between the primary germinal layer. We may call these the *coelomates* and *acoelomates*. The former are then also called *coelomates* or *coelomates*, and the latter *acoelomates*. This division is the more important on the *metazoa* (without *coelom*) have no blood and blood-vessels, nor a coelom. The *coelomates* (with *body-cavity*) have a generally an *acoelom*, and blood and blood-vessels. These are first those belonging to the *coelomates*—the *metazoa* ("primitive", *metazoa*), *sponges*, *coelomates*, and *metazoa*. Of the *coelomates* we can distinguish six classes: the *metazoa* at the bottom, *metazoa* (the common *metazoa* group) derived from the *metazoa* of them the other *metazoa* group of the *metazoa*—the *metazoa*, *metazoa*, *metazoa*, *metazoa*, *metazoa*, and *metazoa*—during evolution these forms.

Next is, in his whole structure, a true *metazoa*, and develops from an *metazoa* even in just the most characteristic way as the other *metazoa*. There can no longer be the slightest doubt about this fundamental fact, nor of the fact that all the *metazoa* form a natural phylogenetic unity, a single mass. The words of the boundary of this mass, from the *metazoa* and the *metazoa* to the *metazoa* and even, have the same characteristic: *metazoa*, *metazoa*, and development of the animal organs, and also in the

same way from the common embryonic form of the *metazoa*. Without going into the difficult question of the degree of this unity, we must emphasize the fact that the *metazoa* mass has no direct affinity whatever to five of the other *metazoa*. These five isolated *metazoa*, not the *metazoa*, *metazoa*, *metazoa*, *metazoa*, and *metazoa*. On the other hand, these are important and, in an indirect, close phylogenetic relation to the other five *metazoa* the *metazoa* (through the *metazoa*), the *metazoa* (through the *metazoa* and *metazoa*), the *metazoa* and *metazoa* (through the *metazoa*), and the *metazoa* (through the *metazoa*).

Now we are to explain these phylogenetic relations in the purpose of our knowledge and to put them in connection to the *metazoa* in the animal kingdom (Chapter II). For the present our task is to make clear the *metazoa* character of each, and separately to point out the chief characteristics of organization by which the *metazoa* mass is fundamentally separated from the other *metazoa* mass of the animal kingdom. Only after these characteristics are understood, shall we be in a position to attack the difficult question of our embryology. The development of even the simplest and lowest *metazoa* from the simple *metazoa* (Fig. II) is so complicated and difficult to follow that it is necessary to understand the original features of the *metazoa* *metazoa* in order to grasp the course of its embryonic evolution. But it is equally necessary to explain our attempts, in this general outline description of the *metazoa*, to the essential facts, and pass by all the *metazoa* *metazoa*, in giving our own and scientific description of the chief features of the *metazoa* and an original organization. I want all the *metazoa* *metazoa*, and *metazoa* myself in this most important *metazoa*.

Each of course, will turn to the reader to be certain that is only of *metazoa* and *metazoa* *metazoa*, or even not *metazoa* at all, in the light of *metazoa* *metazoa* and *metazoa*. For instance, the *metazoa* and *metazoa* *metazoa* and the *metazoa* are *metazoa* in the *metazoa*. It is true that these parts are very important *metazoa*; but for the *metazoa* *metazoa* of the *metazoa* they are not essential, because they are only found in the *metazoa*, not the *metazoa*, *metazoa*. The lowest *metazoa* have

whether shall not vertebrate, and no substitution or fusion. Even the human embryo passes through a stage in which it has no skull or vertebra; the trunk is quite simple, and there is just an inner of arms and legs. At this stage of development man, like every other higher vertebrate, is essentially similar to the simplest vertebrate form, which we now find in only one living specimen. The earliest vertebrates that mark the clearest stage—undoubtedly the most interesting of all the vertebrates after man—is the lamprey lancelet or amphioxus, to which we have already allude referred. As we are going in study is more closely kept on (Chapters XVI and XVII), I will only make one or two passing observations on it here.

The amphioxus lives buried in the mud of the sea. It is about one or two centims in length, and has, when fully developed, the shape of a very simple, longish, lanceolate leaf; hence its name of the lancelet. The narrow body is compressed on both sides, slightly greatly passed at the feet and hind ends. Within exposure of external appendages or articulation of the body into head, neck, trunk, abdomen, etc. Its whole shape is so simple that the first observer ever thought it was a simple animal. It was not until much later—half a century ago—that the ray creature was studied more carefully, and was found to be a true vertebrate. More recent investigations have shown that it is of the greatest importance in connection with the comparative anatomy and ontogeny of the vertebrates, and therefore with human phylogeny. The amphioxus provides the great source of the origin of the vertebrates from the invertebrate condition, and in its development and structure connects directly with various lower invertebrates, the mollusks.

When we make a number of sections of the body of the amphioxus, strictly vertical longitudinal sections through the whole body from end to end, and necessarily transverse sections from right to left, we get anatomic pictures of the utmost interest (cf. Figs. 98-100). In the main they correspond to the plan which we saw, with the aid of comparative anatomy and ontogeny, of the primitive type or build of the vertebrate—the body without form to which the whole class owes its origin. As we take the physiognomic study of the vertebrate stem to its highest degree, and assume a common

origin from a primitive plan-form for all the vertebrates, from amphioxus to man, we are justified in forming a definite morphological idea of this primitive vertebrate (*Protophylan* or *Vertebrium*). We need only imagine a few slight and unessential changes in the real sections of the amphioxus in order to have this ideal anatomic figure or diagram of the primitive vertebrate form, as we see in Figs. 98-100. The amphioxus depicts in this form this primitive form that we may in a certain sense describe it as a simplified "primitive vertebrate."

The main form of our hypothetical primitive vertebrate was in all essence very simple, and probably more or less similar to that of the lancelet. The lateral or bilaterally symmetrical body in strict had not protrusions and appendages at the sides (Figs. 98-100), and in section (Figs. 101, 102). There are no external articulations and no external appendages, in the shape of limbs, legs, or feet. On the other hand, the division of the body into two major head and trunk, was probably clearer in *Protophylan* than it is in the fish-shaped *amphioxus*. In both respects the head or head-end of the body contains different organs from the trunk, and different on the dorsal from on the ventral side. As this important division is found as in the fish aspect, the remarkable similarity of the structure of the vertebrates, we may assume that it was also found in the *protophylan*, the common ancestor of both classes. It is also very pronounced in the young larva of the cyclostomes; the fact is particularly interesting, as this phylogeny is in itself, or in other respects also an important connecting-link between the highest vertebrates and the invertebrates.

The head of the invertebrate, or the anterior half of the body (both of the real amphioxus and the ideal *protophylan*), contains the branchial (gills) gut and heart in the ventral section and the brain and sense-organs in the dorsal section. The trunk, or posterior half of the body, contains the digestive (food) gut and ventral

* The third form of the vertebrate as given in Figs. 98-100 is a hypothetical outline or diagram, but has been closely constructed for the head of the amphioxus, but with a system of vertical longitudinal sections and ventral and ventral of the trunk and appendages on the one hand, and of the vertebrates and invertebrates on the other. This diagram, however, is not intended to be a "more perfect" but merely an attempt to show some hypotheticality of the structure and form of the vertebrate stem, as did "amphioxus."

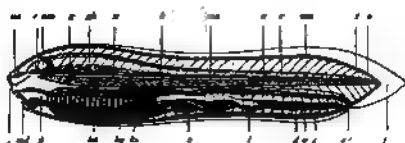


FIG. 94.



FIG. 95.



FIG. 96.



FIG. 97.

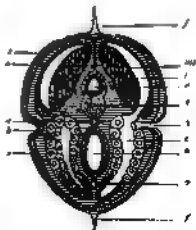


FIG. 98.

FIG. 94-98.—The head primitive vertebrate (approximately 188). FIG. 94, head-view (from the left); FIG. 95, head-view (from the right); FIG. 96, head-view (from the left); FIG. 97, transverse section of the trunk (to the left through the pharynx, to the right through the gill-chamber); FIG. 98, transverse section of the trunk (to the right a pharyngeal section is shown). a, notochord; b, notochord; c, notochord; d, notochord; e, notochord; f, notochord; g, notochord; h, notochord; i, notochord; j, notochord; k, notochord; l, notochord; m, notochord; n, notochord; o, notochord; p, notochord; q, notochord; r, notochord; s, notochord; t, notochord; u, notochord; v, notochord; w, notochord; x, notochord; y, notochord; z, notochord.

FIG. 94-98.—The head primitive vertebrate (approximately 188). FIG. 94, head-view (from the left); FIG. 95, head-view (from the right); FIG. 96, head-view (from the left); FIG. 97, transverse section of the trunk (to the left through the pharynx, to the right through the gill-chamber); FIG. 98, transverse section of the trunk (to the right a pharyngeal section is shown). a, notochord; b, notochord; c, notochord; d, notochord; e, notochord; f, notochord; g, notochord; h, notochord; i, notochord; j, notochord; k, notochord; l, notochord; m, notochord; n, notochord; o, notochord; p, notochord; q, notochord; r, notochord; s, notochord; t, notochord; u, notochord; v, notochord; w, notochord; x, notochord; y, notochord; z, notochord.

glands in the ventral part, and the spinal marrow and roots of the nerves in the dorsal part.

In the longitudinal section of the bill vertebrate (Fig. 98) we have in the middle of the body a thin and flexible, but stiff cylindrical rod, pushed at both ends (ab). It runs the whole length through the middle of the body, and forms, as the central skeletal axis, the original structure of the later vertebral column. This is the axial rod, or *axial chord*, also called *chorda notochorda*, *vertebral cord*, *axial cord*, *dorsal cord*, *notochorda*, or, briefly, *chorda*. The solid, but flexible and elastic, axial rod consists of a cartilaginous mass of cells, and forms the local axial skeleton of dorsal bones of the body; it is only found in vertebrates, and man, and in no other animals. In the first structure of the spinal column it has the same rod-like appearance in all vertebrates, from the simplest to man. But it is only in the amphibians and the reptiles that the axial rod retains its simplest form throughout life. In man and all the higher vertebrates it is found only in the earlier embryonic period, and is afterwards replaced by the articulated vertebral column.

The axial rod or chorda is the real solid chief axis of the vertebrate body, and at the same time corresponds to the axial longitudinal, and serves to direct us with some precision in the construction of the principal organs. We therefore take the vertebrate-body in its original, natural disposition, in which the long-axis lies horizontally, the dorsal side upward and the ventral side downward (Fig. 98). When we make a vertical section through the whole length of the long axis, the body divides into two equal and symmetrical halves, right and left. In each half we have originally the same organs in the same disposition and connection; only their disposal is related to the vertical plane of section, or sagittal plane. It is easily covered: the left half is the reflection of the right. We call the vertical plane of section the *sagittal plane* (the *axial plane* of section that divides the two halves the *sagittal* ("arrow") axis, or "dorsal-ventral axis," goes from the back to the belly, corresponding to the sagittal plane of the skull. But when we make a horizontal longitudinal section through the chorda, the whole body divides into a dorsal and a ventral half. The line of section that passes through

the body from right to left is the transverse, frontal, or lateral axis.

The two halves of the vertebrate body that are separated by this horizontal transverse axis and by the chorda have quite different characters. The dorsal half is mainly the animal part of the body, and contains the greater part of what are called the animal organs, the nervous system, muscular system, excretory system, etc.—the instruments of movement and sensation. The ventral half is essentially the vegetative half of the body, and contains the greater part of the vertebrate's vegetal system, the visceral and vascular systems, animal system, etc.—the instruments of nourishment and reproduction. Hence in the construction of the dorsal half it is chiefly the outer, and in the construction of the ventral half chiefly the inner, germinal layer that is engaged. Each of the two halves develops in the shape of a tube, and encloses a cavity in which another tube is found. The dorsal half contains the upper spinal-cord cavity or ventral canal above the chorda, in which lies the tube-shaped central nervous system, the medullary tube. The ventral half encloses the much more spacious ventral cavity or body-cavity underneath the chorda, in which we find the alimentary canal and all its appendages.

The medullary tube, as the central nervous system or psychic organ of the vertebrate is called at its first length, consists, in man and all the higher vertebrates, of two different parts: the large brain contained in the skull, and the long spinal cord which stretches from above over the whole dorsal part of the trunk. Even in the primitive vertebrate the composition is plainly indicated. The fore half of the body, which corresponds to the head, encloses a heart-shaped vesicle. The brain (Fig. 99). This is prolonged backwards into the thin cylindrical tube of the spinal marrow (Fig. 100). Hence we find here the very important psychic organ, which accomplishes sensation, will, and thought, in the vertebrate, in its simplest form. The thick wall of the nerve-tube which runs through the long axis of the body immediately over the axial rod contains a narrow central canal filled with fluid (Figs. 99-100 r). We still find the medullary tube in the very simple form for a time in the embryo of all the vertebrates, and it remains this form in the amphioxus throughout life.

only in the latter case the cylindrical medullary tube barely indicates the separation of brain and spinal cord. The human medullary tube runs nearly the whole length of the body above the pharynx, in the shape of a long thin tube of almost equal diameter throughout, and there is only a slight swelling of it right at the base to represent the rudiment of a cerebral lobes. It is probable that this peculiarity of the amphibians is connected with the partial atrophy of its base, as the anterior horns in the old head and the young cyprinoids on the other closely show a dilation of the posterior horn, or head marrow, from the thimble, to the spinal marrow.

Probably as most seen in the comparative anatomy of the defective organs of the nervous system, which we will describe later (Chapter XVI) *Protophytes*, on the other hand, probably had some pairs of ommatidia, though of a simple character, a pair of, or a single sensory depression, right in front (Fig. 98, *op. no.*) a pair of eyes (*oc.*) in the lateral walls of the head, and a pair of simple sensory vesicles (*g.*) behind. There was also perhaps a single parietal or "plated" eye at the top of the head (*epidermis*, *e.*).

In the vertical median plane for middle plane, dividing the bilateral body into right and left halves, we have in the anterior, unbroken the chorda, the stomodæum and cerebral tube, and above it the medullary tube, and above the latter a membranous partition of the two halves of the body. With this partition is continued the sheet of ectodermis (cuticle) with as a double tube for the medullary tube with the underlying chorda, and in the dorsal, called the chord-duct (*protophyte*). It continues from the dorsal and ventral part of the stomodæum, which we shall call the stomodæum or "stomodæum" as the anterior embryo. In the latter the chief part of the stomodæum—the ventral stomodæum and stoma—develops from the chord-duct; in the anterior it continues as a simple tube, as a soft connective matter, from which are formed the membranous partitions between the various muscular plates or segments (Fig. 98, *op. no.*).

To the right and left of the stomodæum, on each side of the medullary tube and the underlying axial rod, we find in all the vertebrates the large masses of muscle that constitute the musculature of the

trunk and affect its movements. Although these are very extremely differentiated and connected in the developed vertebrates (corresponding to the various parts of the body skeleton), in our ideal primitive conditions we can distinguish only two parts of these great muscles, which run the whole length of the body parallel to the chorda. There are the upper (dorsal) and lower (ventral) lateral muscles of the trunk. The upper (dorsal) muscles, or thoracic and dorsal muscles (Fig. 98, *op. no.*), form the thick mass of flesh on the back. The lower (ventral) muscles, or the ventral muscles of the belly, form the body wall of the abdomen. Each set are segmented, and consist of a double row of muscular plates (Fig. 98, *op. no.*), the number of these segments determines the number of joints of the trunk, or segments. The segments are also derived from the thick wall of the stomodæum (Fig. 98, *op. no.*).

Outside this muscular tube we have the external envelope of the vertebrate body, which is taken up the ectoderm or cutis. This strong and thick envelope consists, in its larger area, chiefly of fat and loose connective tissue, and in its upper layer of numerous muscles and nerves conducting things. It covers the whole surface of the body, and in all the vertebrates it is in the anterior the stomodæum a sheet of connective tissue, or stomodæum "reticulation" (*stomodæum*, Fig. 98, *op. no.*).

Immediately above the surface in the outer skin (*epidermis*, *e.*), the general covering of the whole outer surface, in the higher vertebrates the hairs, scales, feathers, skin, scales, etc., grow out of the epidermis. It consists, with all its appendages and products, of simple cells, and has no blood-vessels. Its cells are connected with the innermost of the sensory nerve. Originally, the outer skin is a perfectly simple covering of the outer surface of the body, composed only of homogeneous cells—a permanent epithelium. In this simplest form, as a developed condition, we find it, at first, in all the vertebrates, and throughout life in the anterior. It afterwards grows thicker in the higher vertebrates, and divides into two parts—an outer, lower common layer; deeper and an inner, outer mucous layer, also a number of internal and internal appendages grow out of it: internally, the hairs, scales, etc., etc., and

heartily, the sweat-glands, fat-glands, etc.

It is probable that in our primitive vertebrate the skin was raised in the middle line of the body in the shape of a vertical fin leister (*f*). A similar fin-like growth round the greater part of the body is found to-day in the amphioxus and the cyclostomes; we also find one in the tail of fish-tarsus and lampreys.

Now that we have considered the external parts of the vertebrate and the general organs, which naturally lie in the dorsal half, above the chorda, we turn to the ventral organs, which lie for the most part in the ventral half, below the chorda. Here we find a large body-cavity or pericardial cavity at all the main points. The abdominal cavity (that occupies the greater part of the cavity) corresponds to only a part of the original cavity, which we considered in the next chapter; hence it may be called the *metacoelom*. As a rule, it is still widely caving the coelom, formerly it was known in animals as the *pleuroperitoneal cavity*. In man and the other mammals (but only in some) the coelomic bladder, once fully developed, has two different cavities, which are separated by a transverse partition—the muscular diaphragm. The fore or pericardial cavity (*pleuro-cavity*) contains the lungs (pulm.), liver, and lungs; the hind or peritoneal or abdominal cavity contains the stomach, small and large intestines, liver, pancreas, kidneys, etc. In the vertebrate embryo, before the diaphragm is developed, the two cavities form a single continuous body-cavity, and we find it thus in all the vertebrates throughout life. The body-cavity is clothed with a delicate layer of cells, the *endo-coelothelium*. In the embryo the coelom is separated both dorsally and ventrally, so that ventral genital organs (placenta) (Fig. 100).

The chief of the viscera in the body-cavity is the alimentary canal, the organ that represents the whole body in the outside. In all the vertebrates it is a long tube, enclosed in the body-cavity and more or less differentiated in length, and has two openings—a mouth for taking in food (Fig. 98, see ref.) and an anus for the ejection of unassimilated matter or excrement (*af*). With the alimentary canal a number of glands are connected which are of great importance for the vertebrate body, and which all grow out of the

anal. (Glands of this kind are the salivary glands. On lungs, the liver, and many smaller glands. Nearly all these glands are wanting in the acornia; probably there were nearly a couple of simple salivary tubes (Fig. 98, see *f*) in the vertebrate ancestor. The wall of the alimentary canal and all its appendages consists of two different layers; the inner cellular lining is the gut-lining-layer, and the outer, fibrous envelope consists of the gut-lining-layer; it is mainly composed of mesoderm tissue which accomplishes the digestive movements of the canal, and of pericardial tissue (fibrin) that forms a firm envelope. We have a continuation of it in the coelothelium, a thin, membrane-like layer, by means of which the alimentary canal is attached to the ventral side of the chorda, occupying the dorsal portion of the two pleuro-peritoneal cavities. The alimentary canal is variously modified in the vertebrates both as a whole and in its several sections, though the original structure is always the same, and is very simple. As a rule, it is longer (often several times longer) than the body, and therefore folded and winding within the body-cavity, especially at the lower end. In man and the higher vertebrates it is divided into several sections, often separated by valves—the mouth, pharynx, oesophagus, stomach, small and large intestine, and rectum. All these parts develop from a very simple structure, which originally (throughout life in the amphioxus) runs from end to end under the chorda in the shape of a straight cylindrical canal.

As the alimentary canal may be regarded morphologically as the oldest and most important organ in the body, it is interesting to understand its essential features in the vertebrate more fully, and distinguish them from non-vertebrate features. In this connection we must particularly note that the alimentary canal of every vertebrate shows a very characteristic division into two portions—a fore and a hind stomach. The fore-stomach is the head-gut or buccal gut (Fig. 98-see *f*, *g*), and a study occupied with respiration. The hind section is the trunk-gut or hepatic gut, which accomplishes digestion (see *af*). In all vertebrates there are formed, at an early stage, in the right and left in the fore-part of the head-gut, certain special cells that have an intimate connection with the original respiratory apparatus of

the vertebrate—the branchial (gill) slits (Fig. 12). All the lower vertebrates, the molluscs, lampreys, and fishes are constantly taking in water at the mouth, and letting it out again by the branchial slits of the gullet. This water serves for breathing. The oxygen contained in it is inspired by the blood-vessels, which spread out on the parts between the gill-slits, the pharynx (Fig. 13). These very characteristic branched cloths and arches are found in the embryo of man and all the higher vertebrates at an early stage of development, just as we find them throughout life in the lower vertebrates. However, these cloths and arches never act as respiratory organs in the mammalia, birds, and reptiles, but gradually develop into quite different parts. Still, the fact that they are found at first in the same form as in the fishes is one of the most interesting proofs of the degree of their three higher chains from the fishes.

Not less interesting and important is an organ that develops from the ventral wall in all vertebrates—the gill-vein or hypobranchial groove. In the molluscs and the annelids it occupies throughout life of a glandular ribbed groove, which runs down from the mouth in the ventral midline bag of the gill-vein, and takes small particles at first to the stomach (Fig. 101 & 11). But in the vertebrates the thyroid gland (thyroid), is developed from it; the gland thus lies in front of the larynx, and which, when embryonically enlarged, forms gills (cervix).

From the beginning we get not only the gills, the organs of water-breathing in the lower vertebrates, but also the lungs, the organs of atmospheric breathing in the five higher classes. In these cases a vascular fold appears in the gullet of the embryo at an early stage, and gradually takes the shape of two spacious sacs, which are afterwards filled with air. These sacs are the two air-breathing lungs, which take the place of the water-breathing gills. But the vascular invagination, from which the lungs arise, is exactly the boundary air-gill vessel, which we call the branching-rib of the fish, and which always is specially enlarged, serving as hydrostatic organ or sucking apparatus. This structure is not found in the lowest vertebrate classes—the molluscs and cyclostomes. We shall see more of it in Vol. II.

The second chief section of the vertebrate, the trunk or Dorsal, which

occupies the greater part of the body, is of very simple construction in the annelids. It consists of two different chambers. The first chamber immediately behind the gill-vein, is the expanded stomach (Fig. 102); the second, narrower and longer chamber, is the straight small intestine (Fig. 103). It issues ventrad on the ventral side by the anus (Fig. 104). Near the base of the two chambers in the dorsal cavity we find the liver, in the shape of a simple tube or blind sac (Fig. 105). In the amphioxus it is single; in the cephalopods it was probably double (Fig. 106, 107).

Chiefly noted morphologically and phylogenetically is the alimentary canal in the annelids to that of the vertebrates, the chief sections of which develop from the three main layers. It consists of two different but directly connected parts, the system of blood-vessels and that of lymph-vessels. In the beginning of the life we find red blood, and in the other colourless lymph. To the lymphatic system belong, first of all, the lymphatic canals proper or absorption canals, which are distributed among all the organs, and absorb the surplus juices from the tissues, and conduct them into the venous blood; but besides these there are the chyle-vessels, which absorb the whole chyle, the matter thus prepared by the alimentary canal from the food, and conduct this also to the blood.

The blood-vessel system of the vertebrate has a very elaborate construction, but seems to have had a very simple form in the primitive vertebrate, as we find it today permanently in the molluscs (the hepatic, pulmonary) and the annelids. We accordingly distinguish [Fig. 108] of all an essential principal part of it two large single blood-vessels, which lie in the dorsal wall of the gut, and run along the alimentary canal in the midline plane of the body, one above and the other underneath the canal. These principal vessels give out numerous branches to all parts of the body, and pass into each other by anastomosis before and behind; we will call them the primitive artery and the primitive vein. The first corresponds to the dorsal vessel, the second to the ventral vessel of the annelids. The primitive or principal artery, usually called the aorta (Fig. 108 at *a*), lies above the gut in the middle line of its dorsal side, and conducts oxidized or arterial blood from the gills to the body. The primitive or principal vein (Fig. 108 at *v*) lies below the

gut, in the middle line of its ventral side, and in therefore also enters the same subcutaneous; it conducts darkened or venous blood back from the body to the gills. At the branched section of the gut in front the two crurae are connected by a number of branches which run in series between the gut-chains. These "branchial vascular arches" (*Fig. 10*) run along the gill-chains and have a direct share in the work of respiration. The anterior prominence of the principal vein which runs on the ventral wall of the gut-gut, and gives off these vascular arches, upwards, is the branchial artery (*Fig. 10*). At the border of the two sections of the ventral vessel it enlarges into a somewhat siphon-shaped tube (*Fig. 9*, see *A*). This is the first caudal of the lungs, which afterwards become a four-lobed pump in the higher vertebrates and man. There is no heart in the amphioxus, probably owing to degeneration in pseudobranchia; the ventral gut-lung probably had the simple form in which we still find it in the ascidia and the urochord of the crinoids (*Fig. 9*, see *B*).

The kidneys, which act as organs of excretion or urinary organs in all vertebrates, have a very different and elaborate construction in the various sections of this class; we will consider them farther in the twenty-ninth chapter. Here I need only mention that in our invertebrate primitive vertebrate they probably had the same form as in the actual amphioxus—the primitive kidneys (*pseudobranchia*). These are originally made up of a double row of little crurae, which directly convey the waste of blood or the urine out of the body cavity (*Fig. 10*, see *A*). The lower portion of these pseudobranchial crurae opens with a siphon-shaped tube the body cavity; the external opening opens in lateral grooves of the epidermis, a couple of longitudinal grooves in the lateral surface of the outer skin (*Fig. 10*, see *B*). The pseudobranchial duct is formed by the closing of the grooves to the right and left of the sides. In all the crinoids it develops as the early stage in the kidney plant; in the amphioxus it seems to be converted into a tube cavity, the arches, or pseudobranchial space.

Next in the kidneys we have the renal organs of the vertebrates. In most of the members of this class the two are united in a single unsegmented system; it is only in a few groups that the urinary and renal organs are separated for the

amphioxus, the cyclostomes, and more common of the fish-class. In man and all the higher vertebrates the renal apparatus is made up of various parts, which we will consider in the twenty-ninth chapter. But in the two lower classes of our class, the crinoids and cyclostomes, they possess merely of simple renal glands or gonads, the ovaries of the female sex and the testes (*gonads*) of the male; the former provide the eggs, the latter the sperm. In the crinoids we always find only one pair of gonads; in the amphioxus several pairs, arranged in succession. They must have had the same form in our hypothetical pseudobranchia (*Fig. 9*, see *A*). These segmental pairs of gonads are the original ventral halves of the metanephroses.

The organs which we have now enumerated in this general survey, and of which we have named the characteristic disposition, are those parts of the organism that are found in all vertebrates without exception in the same position to each other, however much they may be modified. We have chiefly had in view the transverse section of the body (*Fig. 10*, see *A*), but in this we can most clearly the distinctive arrangement of them. But to complete our picture we must also consider the segmental or metanephroses formation of them, which has yet been hardly noticed, and which is seen best in the longitudinal section. In man and all the more advanced vertebrates the body is made up of a series or stack of similar members, each ordered each other in the long axis of the body—One segment or metanephroses of the organism. In man these homogeneous parts number thirty-three in the trunk, but they run to several hundred in many of the vertebrates (such as serpents or eels). As the internal articulation or connection is usually found in the ventral section and the surrounding processes, the external or ventral ones were formerly called *metanephroses*. As a fact, the articulation is by no means wholly determined and caused by the skeleton, but by the muscular system and the segmental arrangement of the kidneys and gonads. However, the comparison from three pre-articulate or unsegmented members a unity, and rightly, put forward as a prevalent observation of the vertebrate, and the manifest division or differentiation of them is of great importance in the various groups of the vertebrates. But on the one hand

task—the derivation of the simple body of the primitive vertebrate from the chordate—is concerned, the articulate parts or metamers, are of secondary interest, and we need not go into them just now.

The characteristic composition of the vertebrate body develops from the embryonic structure in the same way in man,

that this manner is just as certain and precise in the case of the origin of man from the mammals. This advanced vertebrate class is also monophyletic, or has evolved from one common stem-group of lower vertebrates (reptiles, and, earlier still, amphibians). This follows from the fact that the mammals are



FIG. 1. A, B, C, D—In sequence of subsequent embryonic stages and adaption (adaptation). A, a girl of about embryonic form (with two nipples on the belly above the large mammary area, from a 350-day-old Berlin woman, who had had children 17 times three times over). B, (from Haeckel's work) of the highest member of the human family, a 10-year-old boy, one year before the large mammary area, from a 450-day-old normal of Würzburg. (From Haeckel's work). C, three years of age, two years on the normal glands and one year above, from a 450-day-old Japanese girl. D, last part of embryo, and part above the normal and two parts of small embryonic organs, from a 450-day-old Würzburg woman. (From Haeckel's work).

as in all the other vertebrates. As all competent experts now admit the monophyletic origin of the vertebrates on the strength of this significant agreement, and this "common descent of all the vertebrates from one original stem-form" is admitted as an historical fact, we have found the answer to "the question of question." We may, therefore, point out

clearly distinguished from the other classes of the stem, not merely in one striking particular, but in a whole group of distinctive characters.

It is only in the mammals that we find the skin covered with hair, the breast-cavity separated from the abdominal cavity by a complete diaphragm, and the larynx provided with an epiglottis. The

mammals shown have three small accessory bones in the symphysis vertebra—a feature that is connected with the characteristic modification of their secondary joint. Their red blood-cells have an nucleus, whereas that is rimmed in all other vertebrates. Finally, it is only in the mammals that we find the remarkable location of the breast structure which has given its name to the whole class—the feeding of the young by the mother's milk. The mammary glands which serve this purpose are interesting in as many ways that we may devote a few lines to them here.

As is well known, the lower mammals, especially those which bring a number of young at a time, have several mammary glands at the breast. Badgers and weas have six pairs, most deer or five pairs, dogs and squirrels four pairs, cats and bears three pairs, most of the ruminants and many of the rodents two pairs, each provided with a teat or nipple (*papilla*). In the various groups of the half-apes (*lemurs*) the number varies a good deal. On the other hand the bear and ape, which only bring one young at a time as a rule, have only one pair of mammary glands, and these are found at the breast, as in man.

These variations in the number or structure of the mammary apparatus (*mammaria*) have become very interesting in the light of recent research on comparative anatomy. It has been shown that it even and the eye to what had independent mammary glands (*Apenninus*) and corresponding ones (*Apenninus*) in both cases. Fig. 107 shows how exact of this idea—A, B, and C of them women, and D of a man. They prove that all the above-mentioned numbers may be found occasionally in man. Fig. 107 A shows the breast of a Polish woman who had had children thirteen times, and who has a pair of small mammary breasts (with two nipples on the left side) above the two normal breasts; this is a common occurrence and the small red spot above the breast is but inadequately represented in scientific drawings of Venus. In Fig. 107 C we have the same phenomenon in a Japanese girl of eleven, who has two nipples on each breast besides (three pairs altogether). Fig. 107 D is a case of twenty-two with four pairs of nipples (two in the dog), a small pair above and two small pairs beneath the large normal ones. The

maximum number of five pairs (as in the cow and badger) was found in a Polish woman of twenty-two who had had several children; milk was given by each nipple; there were three pairs of rudimentary nipples above and one pair underneath the normal and very large breasts (Fig. 107 B).

A number of recent investigations (especially among rodents) have shown that these things are not uncommon in the male as well as the female sex. They can only be explained by evolution, which arranges them so wisely and least hardly. The earlier ancestors of all the placentals (including man) were four-placental, which had, like the badger (one of the oldest forms of the living placental), several mammary glands (five or more pairs) in the abdominal skin. In the ape and man only a couple of them are normally developed, but from time to time we get a development of the atrophied structures. Special notice should be taken of the arrangement of these mammary mammae; they form, as in nearly man in Fig. 107 B and D, two long rows, which diverge forward towards the arm-pits, and converge behind to the middle line (towards the loins). The milk-glands of the polymammal lower placentals are arranged in similar rows.

The phylogenetic explanation of polymammia, as given in comparative anatomy, has lately found considerable support in surgery. Hans Schmidt, E. Schenck, and others, have found that there are always in the human embryo at the sixth week (when it is three-fifths of an inch long) the rudimentary traces of five pairs of mammary glands, and that they are arranged at regular distances in two lateral and divergent lines, which correspond to the mammary line. Only one pair of them—the central pair—are normally developed, the others atrophying. Hence there is for a time in the human embryo a normal hypermammia, and this can only be explained by the descent of man from lower placentals (bears) with several pairs.

But the milk-gland of the mammal has a great morphological interest from another point of view. This organ for feeding the young in man and the higher mammals is, as is known, found in both sexes. However, it is usually active only in the female sex, and inside the valuable "mother's milk"; in the male sex it is

small and inactive, a real rudimentary organ of no physiological interest. Nevertheless, in certain cases we find the breast as fully developed in men as in women, and it may give milk for feeding the young.

We have a striking instance of this *gynecomastia* (large milk-giving breasts in a male) in Fig. 104. I owe the photograph (taken from life) to the kindness of Dr. Grasslin, of Athens, a German physician, who has rendered service by a number of anthropological observations (for instance, in several cases of failed

my stay in Ceylon (at Bellagenna) in 1881. A young Cinghalese in his twenty-fifth year was brought to me as a curious hermaphrodite, half-man and half-woman. His large breasts gave plenty of milk; he was employed as "male nurse" to suckle a new-born infant whose mother had died at birth. The outline of his body was softer and more feminine than in the Greek shown in Fig. 104. As the Cinghalese are small of stature and of graceful build, and as the men often resemble the women in clothing (upper part of the body naked, female dress on the lower



FIG. 104.—A Greek gynecomast.

ones). The gynecomast in question is a Greek recruit in his twentieth year, who has both normally developed male organs and very pronounced female breasts. It is noteworthy that the other features of his structure are in accord with the softer form of the female sex. It reminds us of the marble statues of hermaphrodites which the ancient Greeks and Roman sculptors often produced. But one man would only be a real hermaphrodite if he had ovaries internally besides the (externally visible) testicles.

I observed a very similar case during

part) and the drooping of the hair (with a comb), I first took the hairless youth to be a woman. The illusion was greater, as in the remarkable case gynecomastia was associated with *cryptorchism*—that is to say, the testicles had kept to their original place in the visceral cavity, and had not travelled in the normal way down into the scrotum. (Cf. Chapter XXIX.) Hence the latter was very small, soft, and empty. Moreover, one could feel nothing of the testicles in the inguinal canal. On the other hand, the male organ was very small, but normally developed. It was

clear that this apparent hermaphroditism also was a real male.

Another case of practical gynecomastia has been described by Alexander von Hornböldt. In a South American forest he found a solitary settler whose wife had died in child-birth. The man had laid the new-born child on his own breast in despair; and the continuous stimulus of the child's sucking movements had reawakened the activity of the mammary glands. It is possible that nervous suggestion had some share in it. Similar cases have been often observed in recent years, even among other male mammals (such as sheep and goats).

The great scientific interest of these facts is in their bearing on the question of heredity. The stem-history of the mammarian rests partly on its embryology (Chapter XXIV.) and partly on the facts of comparative anatomy and physi-

ology. As in the lower and higher mammals (the monotremes, and most of the marsupials) the whole lactiferous apparatus is only found in the female; and as there are traces of it in the male only in a few younger marsupials, there can be no doubt that these important organs were originally found only in the female mammal, and that they were acquired by males through a special adaptation to habits of life.

Later, these female organs were communicated to both sexes by heredity; and they have been maintained in all persons of either sex, although they are not physiologically active in males. This normal permanence of female lactiferous organs in both sexes of the higher mammals and men is independent of any selection, and is a fine instance of the much-disputed "inheritance of acquired characters."

CHAPTER XII.

EMBRYONIC SHIELD AND GERMINATIVE AREA

THE three higher classes of vertebrates which we call the amniotes—the mammals, birds, and reptiles—were rapidly distinguished by a number of peculiarities of their development from the five lower classes of the stem—the animals without an amnion (the anamniotes). All the amniotes have a distinctive embryonic membrane known as the amnion (or "water-membrane"), and a special embryonic appendage—the allantois. They have, further, a large yolk-sac, which is filled with food-yolk in the reptiles and birds, and with a corresponding clear fluid in the mammals. In consequence of these later-acquired structures, the original features of the development of the anamniotes are so much altered that it is very difficult to reduce them to the paleogenetic embryonic processes of the lower amnion-less vertebrates. The gastrula theory shows us how to do this, by representing the embryology of the lowest vertebrates, the skull-less morphians, as

the original form, and deducing from it, through a series of gradual modifications, the gastrulation and coelomization of the cranulata.

It was somewhat fatal to the true conception of the chief embryonic processes of the vertebrates that all the older embryologists, from Malpighi (1687) and Wolf (1795) to Duer (1828) and Remak (1850), always started from the investigation of the hen's egg, and transferred to man and the other vertebrates the impressions they gathered from this. This classical object of embryological research is, as we have seen, a source of dangerous errors. The large round food-yolk of the bird's egg causes, in the first place, a flat discoidal suspension of the small gastrula, and then a distinctive development of this thin round embryonic disk that the controversy as to its significance occupies a large part of embryological literature.

One of the most unfortunate errors that this led to was the idea of an original

antithesis of germ and yolk. The latter was regarded as a foreign body, extrinsic to the real germ, whereas it is properly a part of it, an embryonic organ of nutrition. Many authors said there was no trace of the embryo until a later stage, and outside the yolk; sometimes the two-layered embryonic disk itself, at other times only the central portion of it (as distinguished from the germinative area, which we will describe presently), was taken to be the first nucleus of the embryo.

primitive spot. This is clearly shown by the oval of the amphibia and cyclostoma, which explain the transition from the yolk-less ova of the amphioxus to the large yolk-filled ova of the reptiles and birds.

It is precisely in the study of these difficult questions that we see the incalculable value of phylogenetic considerations in explaining complex ontogenetic facts, and the need of separating ontogenetic phenomena from paleogenetic.

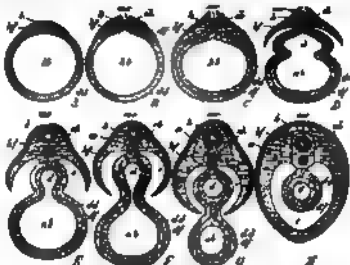


FIG. 109.—Development of the fluid-membrate embryo from the yolk-mass, in transverse section (teleostomus). A. The germinal disk (*a, b*) has but one pole (note the branching *g*); *h* is the middle of the peripheral disk we find the embryonic groove (*c*), and underneath *h* the chorda (*e*). B. The gut-bladder (*d*) has been induced by the gut (*c*); *g* is the midline (*g*) and the gut-bladder (*d*) is the gut (*c*). C. The gut-bladder (*d*) is the gut (*c*). D. The gut-bladder (*d*) is the gut (*c*). E. The gut-bladder (*d*) is the gut (*c*). F. The gut-bladder (*d*) is the gut (*c*). G. The gut-bladder (*d*) is the gut (*c*). H. The gut-bladder (*d*) is the gut (*c*). The embryo and chorda are indicated.

The embryo has the midline running throughout. A. embryo, or embryonic tube, B. embryonic tube, C. embryonic tube, D. embryonic tube, E. embryonic tube, F. embryonic tube, G. embryonic tube, H. embryonic tube.

In the light of the quantum theory it is hardly necessary to dwell on the defects of this earlier view and the erroneous conclusions drawn from it. In reality, the first segmentation-cell, and even the stem-cell itself and all that issues therefrom, belong to the embryo. As the large original yolk-mass in the undivided egg of the bird only represents an increase in the greatly enlarged ovum, so the later contents of its embryonic yolk-mass (whether yet segmented or not) are only a part of the ectoderm which forms the

This is particularly clear as regards the comparative embryology of the vertebrates, because here the phylogenetic unity of the stem has been already established by the well-known facts of paleontology and comparative anatomy. If this unity of the stem, on the basis of the amphioxus, was always borne in mind, we should not have these errors constantly recurring.

In many cases the ontogenetic relation of the embryo to the food-yolk has until now given rise to a quite wrong idea of

the first and most important embryonic processes in the higher vertebrates, and has occasioned a number of false theories in connection with them. Until thirty years ago the embryology of the higher vertebrates always started from the position that the first structure of the embryo is a flat, leaf-shaped disk; it was for this reason that the out-layers that surround this germinal disk (also called germinative area) are called "germinal layers." This flat germinal disk, which is raised at first and then oval, and which is often described as the head or chorion in the laid hen's egg, is found at a certain part of the surface of the large granular yolk-yolk. I am convinced that it is nothing else than the dilated, flattened gastrula of the birds. At the beginning of gastrulation the flat embryonic disk curves outward, and separates on the inner side from the underlying large yolk-ball. In this way the flat layers are converted into tubes, their edges folding and joining together (Fig. 105). As the embryo grows on the surface of the food-yolk, the inner becomes smaller and smaller, it is completely surrounded by the germinal layers. Later still, the remainder of the food-yolk only forms a small raised area, the yolk-are or umbilical vesicle (Fig. 105 ab). This is enclosed by the visceral layer, is connected by a thin stalk, the yolk-duct, with the central part of the gut-tube, and is finally, in most of the vertebrates, entirely absorbed by this (H). The point at which this takes place, and where the gut finally closes, is the umbilical canal. In the monotremes, in which the remainder of the yolk-are remains without and atrophic, the yolk-duct at length penetrates the visceral wall. At birth this umbilical cord proceeds from here, and the point of closure remains throughout life in the skin as the navel.

As the older embryology of the higher vertebrates was mainly based on the chick, and regarded the epithelium of embryo (or formative-yolk) and food-yolk (or yolk-mass) as original, it had also to look upon the flat leaf-shaped structure of the germinal disk as the primitive embryonic form, and mentioned the fact that hollow grooves were formed of these flat layers by folding, and closed ones by the joining together of their edges.

This idea, which dominated the whole treatment of the embryology of the higher vertebrates until thirty years ago, was

totally false. The gastrula theory, which has its chief application here, teaches us that it is the very reverse of the truth. The cup-shaped gastrula, in the body-end of which the two primary germinal layers appear from the first as closed tubes, is the original embryonic form of all the vertebrates, and all the multicellular invertebrates; and the flat germinal disk with its superficially expanded germinal layers is a later, secondary form, due to the congeneric flattening of the large food-yolk and the gradual spread of the germ-layers over its surface, thence the actual folding of the germinal layers and their conversion into tubes is not an original and primary, but a much later and tertiary, evolutionary process. In the phylogeny of the vertebrate embryonic process we may distinguish the following three stages:—

A. First Stage Primary (monotreme) embryonic process

The gastrula layer does not rise above the level of the food-yolk, but remains flat, thus forming a germinal disk, the surface of which is covered by the epithelial germinal layer (Amphioxus).

B. Second Stage Secondary (monotreme) embryonic process

The gastrula layer does not rise above the level of the food-yolk, but remains flat, thus forming a germinal disk, the surface of which is covered by the epithelial germinal layer (Amphioxus).

C. Third Stage Tertiary (monotreme) embryonic process

The gastrula layer does not rise above the level of the food-yolk, but remains flat, thus forming a germinal disk, the surface of which is covered by the epithelial germinal layer (Amphioxus).

As this theory, a logical conclusion from the gastrula theory, has been fully substantiated by the comparative study of gastrulation in the last few decades, we must exactly reverse the old-time prevalent mode of treatment. The yolk-are is not to be treated, as was done formerly, as if it were merely an anathema to the embryo, but as an essential part of it, a part of its original tube. The primitive gut of the gastrula has, on this view, been divided into two parts in the higher animals as a result of the congeneric flattening of the food-yolk—the permanent gut (metagastrum), or permanent alimentary canal, and the yolk-are (Amphioxus), or umbilical vesicle. This is very clearly shown by the comparative ontogeny of the fishes and amphibia. In these cases the whole yolk undergoes change at first, and forms a yolk-glass, composed of yolk-cells, in the visceral wall

of the primitive gut. But afterwards becomes so large that a part of the yolk does not divide, and is used up in the yolk-sac that is cut off outside.

When we make a comparative study of the embryology of the amphioxus, the frog, the chick, and the rabbit, there cannot, in my opinion, be any further doubt as to the truth of this position, which I have held for thirty years. Hence in the light of the gastrula theory we must regard the features of the amphioxus as the only and real primitive structure among all the vertebrates, departing very little from the paleozoic embryonic form. In the cyclostoma and the frog these features are, on the whole, not much altered comparatively, but

The oldest, oviparous mammals, the monotremes, behave in the same way as the reptiles and birds. But the corresponding embryonic processes in the viviparous mammals, the marsupials and placentals, are very elaborate and dissimilar. They were formerly quite misinterpreted; it was not until the publication of the studies of Edward van Beneden (1855) and the later research of Sedgwick, Kupffer, Habi, and others, that light was thrown on them, and we were in a position to bring them into line with the principles of the gastrula theory and trace them to the embryonic forms of the lower vertebrates. Although there is no independent food-yolk, apart from the nutritive yolk, in the mammalian ovum, and although its segmentation is total and synchronous, nevertheless a large yolk-sac is formed in their embryos, and the "embryo proper" spreads leaf-wise over its surface, as in the reptiles and birds, which have a large food-yolk and partial segmentation. In the mammals, as well as in the latter, the flat, leaf-shaped germinal disk separates from the yolk-sac, and its edges join together and form tubes.

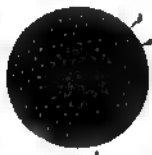


FIG. 106.

FIG. 106.—Flat rabbit embryo (blastoderm) of a rabbit (the "blastula") as viewed dorsiventrally of about midway, a center (ventral) to (dorsal) 2 double row of cells, forming the entire wall of the blastoderm, a group of dark cells, representing the ventral layer of the blastoderm.



FIG. 107.

FIG. 107.—Chick embryo as above. Letters as above. (From Haeckel.)

they are very much so in the chick, and most of all in the rabbit. In the latter, gastrula of the amphioxus and in the hooded gastrula of the lamprey and the frog the germinal layers are found to be closed tubes or vesicles from the first. On the other hand, the chick-embryo (in the new laid, but not yet hatched, egg) is a flat circular disk, and it was not easy to recognize this as a real gastrula. Reicher and Goettin have, however, achieved this. As the discoid gastrula grows round the large globular yolk, and the permanent gut then separates from the outlying yolk-sac, we find all the processes which we have shown (diagrammatically) in Fig. 106—processes that were hitherto regarded as principal ones, whereas they are merely secondary.

How can we explain this curious anomaly? Only as a result of very characteristic and peculiar ontogenetic modifications of the embryonic process, the real causes of which must be sought in the changes in the rearing of the young on the part of the viviparous mammals. These are clearly connected with the fact that the ancestors of the viviparous mammals were oviparous animals like the present monotremes, and only gradually became viviparous. This can no longer be questioned now that it has been shown (1884) that the monotremes, the lowest and oldest of the mammals, still lay eggs, and that these develop like the ova of the reptiles and birds. Their nearest descendants, the marsupials, formed the habit of retaining the eggs, and developing them in the

subduct; the latter was then converted into a womb (uterus). A nutritive fluid that was secreted from the wall, and passed through the wall of the blastula, now served to feed the embryo, and took the place of the food-yolk. In this way the original food-yolk of the monostem was gradually atrophied, and at last disappeared so completely that the partial ovum-germination of their descendants, the rest of the monostem, once more became total. From the atrophied wall of the former was evolved the distinctive epiblastula of the latter.

It is only by this phylogenetic explanation that we can understand the formation and development of the placenta, and hitherto totally misunderstood, blastula of the mammal. The vesicular condition of the mammal embryo was discovered one year ago (1897) by Wagner de Graaf. He found in the uterus of a rabbit four days after insemination small, round, loose, transparent vesicles, with a double envelope. However, Graaf's discovery passed without recognition. It was not until 1897 that these vesicles were rediscovered by Bloor, and then more closely studied in 1903 by Bischoff in the rabbit (Figs. 106, 107). They are found in the womb of the rabbit, the dog, and other small mammals, a few days after copulation. The mature ova of the mammal, when they have left the ovary, are fertilized either here or in the oviduct immediately afterwards by the invading spermatozoa. (As to the sperm and oviduct see Chapter XXIX.) The cleavage and formation of the gastrula takes place in the oviduct. Either here in the oviduct or after the mammal gastrula has passed into the uterus it is converted into the globular vesicle which is shown externally in Fig. 106, and in section in Fig. 107. The thick, outer, structureless envelope that encloses it is the original envelope or *zona pellucida*, modified and clothed with a layer of albumin that has been deposited on the outside. From this stage the envelope is called the external membrane, the *primary chorion* or *pro-chorion* (a). The real wall of the vesicle

enclosed by it consists of a simple layer of monodermic cells (b), which are flattened by internal pressure, and generally homogeneous; a light nucleus shines through their fine-grained protoplasm (Fig. 106). At one part (c) inside this hollow ball we find a decidual sac, formed of darker, softer, and rounder cells, the dark-grained endodermic cells (Fig. 106).

The characteristic embryonic form that the developing mammal now exhibits has up to this present usually been called the "blastula" (Bischoff), "maculipend embryo" (Bloor), "vesicular embryo" (Wagner de Graaf), or, briefly, *blastosphere*. The wall of the hollow vesicle, which consists of a single layer of cells, was called the "blastoderm" and was supposed to be equivalent to the out-layer of the mass mass that forms the wall of the real blastula of the amphioxus and



FIG. 106.

FIG. 107.

FIG. 106.—Four blastodermic cells from the embryonic vesicle of the rabbit.

FIG. 107.—Two endodermic cells from the embryonic vesicle of the rabbit.

many of the invertebrates (such as *Hydra*, Figs. 29, 30, 31). Formerly this real blastula was generally believed to be equivalent to the embryonic vesicle of the mammal. However, this is by no means the case. What is called the "blastula" of the mammal and the real blastula of the amphioxus and many of the invertebrates are totally different embryonic structures. The inner (blastula) is paleogonic, and provides the formation of the gastrula. The former (blastodermic vesicle) is neogonic, and follows gastrulation. The globular wall of the blastula is a real blastoderm, and consists of homogeneous (blastodermic) cells; it is not yet differentiated into the two primary germinal layers. But the globular wall of the mammal vesicle is the differentiated ectoderm, and at one point in it we find a circular disk of quite different cells—the gastrula. The round

* It is this and the other processes the fertilization of the egg, probably takes place, so a cell, so the embryo, from the egg, which comes from the egg, and so the blastula of the *Gastrula* cells, and under the inner surface of the embryo, over the whole space, and so the outer wall, which pass into the uterus of the embryo, and from there into the external surface of the embryo. The embryo, which is the embryo, is the embryo.

cavity, filled with fluid, inside the real blastula is the segmentation-cavity. But the similar cavity within the mammal vesicle is the yolk-sac cavity, which is

which we have considered previously (Chapter IX). For these reasons it is very necessary to recognise the secondary embryonic vesicle in the mammal (*gastrula*



FIG. 170.



FIG. 171.

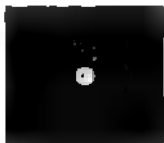


FIG. 172.



FIG. 173.

FIG. 170.—Cross of a radicle from the stern, run with of an oval of diameter. The structure is a solid, but with a hole, from the central cavity (a) to the middle of the structure, we see the first of the cells (b) and (c) at the edge of which (d) is not lost of the structure (e) is already beginning to appear. (Figs. 170-173 from Huxley.)

FIG. 171.—The same cross, seen in profile. Later on in Fig. 172.

FIG. 172.—Cross of a radicle from the stern, run with of an oval of diameter. The structure is a solid, but with a hole, from the central cavity (a) to the middle of the structure, we see the first of the cells (b) and (c) at the edge of which (d) is not lost of the structure (e) is already beginning to appear. (Figs. 170-173 from Huxley.)

FIG. 173.—The same cross, seen in profile. Later on in Fig. 174.

FIG. 174.—Cross of a radicle from the stern, run with of an oval of diameter. The structure is a solid, but with a hole, from the central cavity (a) to the middle of the structure, we see the first of the cells (b) and (c) at the edge of which (d) is not lost of the structure (e) is already beginning to appear. (Figs. 170-173 from Huxley.)



FIG. 174.

connected with the incipient gut-cavity. This primitive gut-cavity passes directly into the segmentation-cavity in the mammal. In consequence of the peculiar ontogenetic changes in their gastrulation,

(*Gastrula* or *Embryonic*) as a characteristic structure peculiar to this class, and distinguished carefully from the primary blastula of the amphioxus and the involution.

The small, circular, whitish, and opaque spot which the gastric disk (Fig. 106) forms at a certain part of the surface of the clear and transparent embryonic vesicle has long been known to science,



FIG. 105.—Germinal area of the embryo, divided into the outer light-colored part (ectoderm) and the peripheral dark area (inner layers). The light area forms the outer part of the embryo, appearing through it.

and ascribed to the germinal disk of the birds and reptiles. Sometimes it has been called the germinal disk, sometimes the germinal spot, and usually the germinal area. From the area the further development of the embryo proceeds. However, the larger part of the embryonic vesicle of the mammal is not directly used for building up the later body, but for the construction of the temporary umbilical vesicle. The embryo separates from this in proportion as it grows at its expense; the two are only connected by the yellicord (the stalk of the yolk-sac), and this maintains the direct communication between the cavity of the umbilical vesicle and the forming visceral cavity (Fig. 105).

The germinative area or gastric disk of the mammal consists at first (like the germinal disk of birds and reptiles) merely of the two primary germinal layers, the ectoderm and endoderm. But soon there appears in the middle of the circular disk between the two a third stratum of cells, the rudiment of the middle layer or mesoderm layer (*mesoderm*). This middle germinal layer consists from the first, as we have seen in the tenth Chapter, of two opposite epithelial plates, the two layers of the coelom-pouches (parietal and visceral). However, in all the amniotes (on account of the large formation of yolk) these thin middle plates are so firmly pressed together that they seem to represent a

single layer. It is thus peculiar to the mammal that the middle of the germinative area is composed of four germinal layers, the two limiting (or primary) layers and the middle layers between them (Figs. 96, 97). These four secondary germinal layers can be clearly distinguished as soon as what is called the *ectoderm* (or "embryonic scale") is seen at the hind border of the germinative area. At the borders, however, the germinative area of the mammal only consists of two layers. The rest of the wall of the embryonic vesicle consists at first (not only for a short time in most of the mammals) of a single layer, the outer germinal layer.

From this stage, however, the whole wall of the embryonic vesicle becomes *triply-layered*. The middle of the germinative area is much thickened by the growth of the outer of the middle layers, and the inner leg or expands at the same time, and increases at the border of the disk all round. Lying close on the outer layer throughout, it grows over its inner surface at all points, covers first the upper and then the lower hemisphere, and at last closes in the middle of the inner layer (Figs. 100-102). The wall of the embryonic vesicle now consists throughout of two layers of cells, the ectoderm without and the endoderm within. It is only in the centre of the circular area, which



FIG. 106.—Gastric disk, with the opaque whitish border of the dark area without.

becomes thicker and thicker through the growth of the middle layers, that it is made up of all four layers. At the same time, small structural tubercles or warts are deposited on the surface of the outer

ovules or prochorion, which has been raised above the embryonic shield (Figs. 112-114 a).

We may now disregard both the outer ovules and the greater part of the



FIG. 113.—Oval embryo of the chick, magnified about 100 times. At the bottom, the embryonic shield lies on a black ground, the ground from which the dark ring and the opaque area above outside it take a white ring. The oval shield in the center also takes white, and at its apex lies on the dark embryonic ground. (From Sturtevant.)

shield, and concentrate our attention on the germinative area and the four-layered embryonic disk. It is here alone that we find the important changes which lead to the differentiation of the first organs. It is immaterial whether we examine the germinative area of the mammal (the rabbit, for instance) or the germinal disk of a bird or a reptile (such as a lizard or tortoise). The embryonic processes we are now going to consider are essentially the same in all members of the three higher classes of vertebrates which we call the amniotes. Man is found to agree in this respect with the rabbit, dog, cat, etc.; and in all these mammals the germinative area undergoes essentially the same changes as in the birds and reptiles. They are most frequently and accurately studied in the chick, because we can have incubated hens' eggs in any quantity at any stage of development. Moreover, the round germinal disk of the chick passes immediately after the beginning of incubation (within a few hours) from the two-

layered to the four-layered stage, the two-layered mammalian developing from the median primitive groove between the ectoderm and endoderm (Figs. 82-93).

The first change in the round germinal disk of the chick is that the cells at its edges multiply more briskly, and form darker nuclei in their protoplasm. This gives rise to a dark ring, more or less sharply set off from the lighter center of the germinal disk (Fig. 115). From this point the latter takes the name of the "light area" (*area pellucida*), and the darker ring is called the "dark area" (*area opaca*). In a strong light, as in Figs. 115-117, the light area seems dark, because the dark ground is seen through it; and the dark area seems whiter. The circular shape of the area now changes into elliptic, and then immediately into oval (Figs. 116, 117). One end grows to be broader and blunter, the other narrower and more pointed, the former corresponds to the anterior and the latter to the posterior section of the subsequent body. At the same time, we can already trace the characteristic bilateral form of the body, the anteroposterior of right and left, before and



FIG. 115.—Four-layered germinal disk of the chick, magnified 100 times. At the bottom, the embryonic shield lies on a black ground, the ground from which the dark ring and the opaque area above outside it take a white ring. (From Sturtevant.)

behind. This will be made clearer by the "primitive streak," which appears at the posterior end.

At an early stage an opaque spot is seen in the middle of the clear germinative

area, and this also passes from a circular to an oval shape. At first this shield-shaped marking is very definite and hardly perceptible; but it soon becomes clearer, and now stands out as an oval shield, surrounded by two rings or areas (Fig. 117). The inner and brighter ring is the remainder of the yolk area, and the dark outer ring the remainder of the opaque area; the opaque shield-like spot itself is the first rudiment of the dorsal part of the embryo. We give it briefly

"most" and "germinative area" are used in many different senses—and this has led to a fatal confusion in embryonic literature—we must explain very clearly the real significance of these important embryonic parts of the ovum. It will be useful to do so in a series of formal principles:—

1. The so-called "first trace of the embryo" in the amniote, or the embryonic shield, in the centre of the yolk area, consists merely of an early differ-

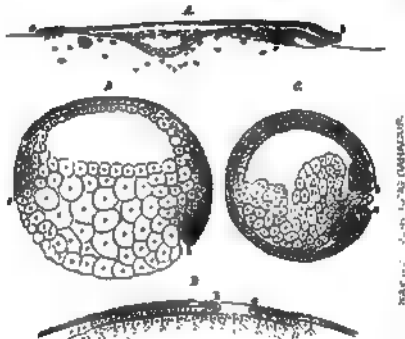


FIG. 116.—Histological sections of the yolk area of various vertebrates. (From *Zeit. f. Anat. u. Entw.*) A, section of a chick (*Gallus gallus*); B, section of a mouse (*Mus musculus*); C, section of a frog (*Rana temporaria*); D, section of an embryo (*Xenopus laevis*). A vertical line in the middle of the yolk area.

the name of embryonic shield or dorsal shield. In most works this embryonic shield is described as "the first rudiment or trace of the embryo," or "primitive embryo." But this is wrong, though it rests on the authority of Baer and Mitchell. As a matter of fact, we already have the embryo in the stem-cell, the granula, and all the subsequent stages. The embryonic shield is simply the first rudiment of the dorsal part, which is the earliest indication. As the older source of "embryonic shield"

indicates the formation of the ridge is dorsal parts.

2. Hence the best name for it is "the dorsal shield," as I proposed long ago.

3. The germinative area, in which the first embryonic blood-vessels appear at an early stage, is not opposed as an external area to the "embryo proper," but is a part of it.

4. In the same way, the yolk sac or the umbilical vessels is not a foreign external

appendage of the ectoderm, but an outlying part of its primitive gut.

5. The dorsal shield gradually separates from the germinal area and the yolk-mass, its edges growing dorsward, and folding together to form ventral plates.

6. The yolk-mass and vessels of the germinal area, which soon spread over its whole surface, are, therefore, real embryonic organs, or temporary parts of the embryo, and have a temporary importance in connection with the nutrition of the growing later body; the latter may be called the "pericardial body" in contrast to them.

The relation of these ontogenetic features of the amniotes to the paleogenetic structures of the older amniotic vertebrates may be expressed in the following theses: The original gastrula, which completely passes over into the embryonic body in the anura, cyclostoma, and amphibia, is early divided into two parts in the amniotes—the embryonic shield, which represents the dorsal outflow of the pericardial body, and the temporary embryonic organs of the germinal area and its blood-vessels, which soon grow over the whole of the yolk-mass. The differences which we find in the various classes of the vertebrates seen in their important particularities can only be fully understood when we bear in mind their phylogenetic relations on the one hand, and, on the other, the ontogenetic modifications of structures that have been brought about by changes in the feeding of the young and the variations in the area of the food-yolk.

We have already described in the sixth chapter the changes which this increase and decrease of the nutritive yolk causes in the form of the gastrula, and especially in the situation and shape of the primitive mouth. The primitive mouth or proboscis is originally a simple round aperture at the lower pole of the long axis, its dorsal lip is above and ventral lip below. In the amphibia this primitive mouth is a little eccentric, or shifted to the dorsal side (Fig. 39). The aperture increases with the growth of the food-yolk in the cyclostoma and ganoidei; in the sturgeon it lies almost on the equator of the round area,

the ventral lip (*a*) is front and the dorsal lip (*b*) behind (Fig. 119 *B*). In the wide-mouthed, circular shield gastrula of the teleostei or primitive fishes, which spreads quite flat on the large food-yolk, the anterior semi-circle of the border of the duct is the ventral, and the posterior semi-circle the dorsal lip (Fig. 119 *A*). The amphibiotic amphibians are directly connected with their earlier fish-ancestors, the dipnoans and ganoidei, and further the eldich actinchi (*Leptacanthus*), they have retained their basal unequal asymmetry, and their small primitive mouth (Fig. 119 *C*, *cd*), detached up by the yolk-stopper, lies at the border of the dorsal and ventral surface of the embryo (at the lower pole of its equatorial axis), and thus applies has an upper dorsal and a lower ventral lip (*A*, *b*). The formation of a large food-yolk followed again in the teleostei of the amniotes, the pentastomes or protoproctes, descended from the amphibia (Fig. 120 *B*). They have the accumulation of the food-yolk well placed only in the ventral wall of the pericardial wall, so that the dorsal gastrulaic mouth lying behind has turned upward, and came to lie on the back of the dorsal "epigastrula" in the shape of the "proctostoma prae", thus (in contrast to the case of the teleostei, Fig. 120 *A*) the dorsal lip (*b*), had to be to lower, and the ventral lip (*a*) behind (Fig. 120 *B*). This feature was transmitted to all the amniotes, whether they retained the large food-yolk (reptiles, birds, and monotremes), or lost it by atrophy (the viviparous mammals).

This phylogenetic explanation of gastrulation and outstulation, and the comparative study of them in the various vertebrates, throw a clear and full light on every ontogenetic phenomenon, as to which the most obscure and confused opinions were prevalent thirty years ago. In this we see especially the high scientific value of the biogenetic law and the careful separation of paleogenetic from ontogenetic processes. To the opponents of this law the real explanation of these remarkable phenomena is impossible. Here, and in every other part of embryology, the true key to the solution lies in phylogeny.

CHAPTER XIII.

DORSAL BODY AND VENTRAL BODY

The earliest stages of the human embryo are, for the reasons already given, either quite unknown or only imperfectly known to us. But as the subsequent embryonic forms in man behave and develop just as they do in all the other mammals, their cannot be the slightest doubt that the preceding stages also are similar. We have been able to see in the ectoderm of the human embryo (Fig. 92) by transverse sections through its primitive mouth, that its two ectoderm-pouches are developed in just the same way as in the

it is in the middle line of this that the primitive mouth appears (Fig. 221 *pe*). The narrow longitudinal groove in it—the so-called “primitive groove”—is, as we have seen, the primitive mouth of the gastrula. In the gastrula-embryo of the mammals, which are much modified comparatively, this slit-shaped proctoderm is lengthened so much that it now occupies the whole of the hinder half of the dorsal shield; as we find in a rabbit-embryo of six to eight days (Fig. 222 *pe*). The two smaller parallel borders that



FIG. 121.—Embryonic condition of a seven-day-old rabbit with oral undergrowth (ventral furrow) from above. *A* from the side. (From Kollmer.) As dorsal shield is rudimentary, that is, in the upper half of the shield it ends up of the two primary gastrular folds, the lower tip is still only from the outer (2) of

rudiments (Fig. 95); moreover, the peculiar course of the gastrulation is just the same.

The germinal area forms in the human embryo in the same way as in the other mammals, and in the middle part of this we have the embryonic shield, the purpose of which we considered in the previous chapter. The next changes in the embryonic disk, or the “ectodermic spot,” take place in corresponding fashion. These are the changes we are now going to consider more closely.

The chief part of the ventral embryonic shield is at first the narrow hinder end;

thence this median furrow runs the side tips of the primitive mouth, right and left. In this way the bilateral-symmetrical type of the vertebrate becomes pronounced. The subsequent head of the nematode as developed from the broader and rounder fore-half of the dorsal shield.

In this fore-half of the dorsal shield a median furrow quickly makes its appearance (Fig. 123 *ff*). This is the broader dorsal furrow or medullary groove, the first beginning of the central nervous system. The two parallel dorsal or medullary swellings that enclose it grow

together over it afterwards, and form the medullary tube. As is seen in transverse sections, it is formed only of the outer germinal layer (Figs. 95, 136). The lips of the primitive mouth, however, lie, as

we know, at the important point where the outer layer breaks over the inner, and from which the two coelomic pouches grow between the primary germinal layers.

Thus the median primitive furrow (*pr*)

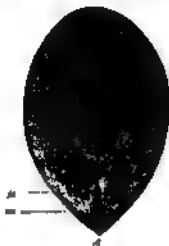


FIG. 137.—Dorsal embryonic shield of the rabbit, 44 or 45 days (different hours of 45 days from Fig. 136). *pr* primitive mouth, *prg* primitive groove, *prg* primitive groove, *pr* primitive mouth, *pr* primitive mouth, *pr* primitive mouth.

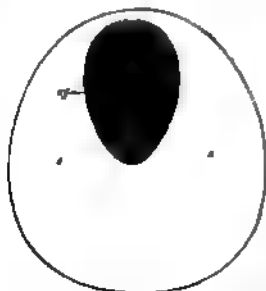


FIG. 138.

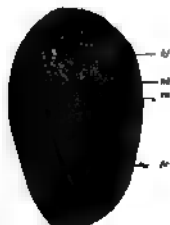


FIG. 139.

FIG. 138.—Dorsal shield (*pr*) and surrounding area of a rabbit-embryo of 45 days. (From Klinger.) *pr* primitive mouth, *prg* primitive groove.

FIG. 139.—Dorsal shield of a rabbit, 45 days. (From von Stauden.) *pr* primitive mouth, *prg* primitive groove, *prg* primitive groove, *pr* primitive mouth, *pr* primitive mouth, *pr* primitive mouth.

in the hind-half and the middle modulatory furrow (*f*) in the fore-half of the oral shield are totally different structures, although the latter seems to a superficial observer to be merely the forward continuation of the former. Hence they



FIG. 124.—Longitudinal section of the cephalopod of *Amphioxus* (from the left). *a*, oral shield; *b*, primitive gut; *c*, modulatory tube; *d*, nerve tube; *e*, notochord; *f*, dorsal primitive groove; *g*, ventral groove. (From Huxley.)

were formerly always confused. The error was the more pardonable as immediately afterwards the two grooves do actually pass into each other in a very remarkable way. The point of transition is the remarkable auroretic canal (Fig. 124 *av*). But the direct connection is but in this established does not last long; the two are soon definitely separated by a partition.

The original *auroretic canal* is a very old embryonic organ, and of great phylogenetic interest. Because it occurs in the same way in all the chordates (both tunicates and vertebrates). In every case it touches or embraces (like an arch) the posterior end of the chorda, which has been developed here in broad out of the middle line of the primitive gut (between the two caudal-folds of the notochord) ("head-process," Fig. 123 *h*). These very ancient and strictly hereditary structures, which have no physiological significance to-day, deserve (as "redundant organs") our closest attention. The tenacity with which the useless auroretic canal has been transmitted down to man through the whole series of vertebrates is of equal interest for the study of descent in general, and the phylogeny of the chordates in particular.

The connection which the auroretic canal (Fig. 123 *av*) establishes between the dorsal nerve-tube (*n*) and the ventral gut-tube (*d*) is seen very

plainly in the amphioxus in a longitudinal section of the cephalopod, as soon as the primitive mouth is completely closed at its hinder end. The modulatory tube has still at this stage an opening at the forward end, the neurocrus (Fig. 83 *ag*). This opening also is afterwards closed. There are then two completely closed canals over each side—the modulatory tube above and the gastric tube below, the two being separated by the chorda. The same features as in the acrania are exhibited by the colored tunicates, the ascidians.

Again, we find the auroretic canal in just the same form and situation in the amphibia. A longitudinal section of a young tadpole (Fig. 125) shows how we may penetrate from the still open prechordal mouth (*x*) either into the wide primitive gut-cavity (*aj*) or the narrow overlying nerve-tube. A little later, when the primitive mouth is closed, the narrow auroretic canal (Fig. 126 *av*) represents the arched connection between the dorsal modulatory canal (*na*) and the ventral gastric canal.

In the amphioxus this original curved form of the auroretic canal cannot be found at first, because here the primitive mouth closes completely over to the

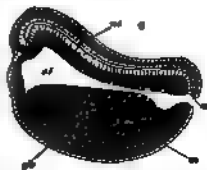


FIG. 125.—Longitudinal section of the stomach of a tadpole. (From Huxley.) *a*, stomach; *b*, primitive groove; *c*, notochord; *d*, ventral groove; *e*, dorsal primitive groove; *f*, dorsal nerve tube; *g*, ventral nerve tube; *h*, head-process; *i*, notochord; *j*, dorsal primitive groove; *k*, ventral groove; *l*, dorsal nerve tube; *m*, ventral nerve tube; *n*, dorsal primitive groove; *o*, ventral groove; *p*, dorsal nerve tube; *q*, ventral nerve tube; *r*, dorsal primitive groove; *s*, ventral groove; *t*, dorsal nerve tube; *u*, ventral nerve tube; *v*, dorsal primitive groove; *w*, ventral groove; *x*, dorsal nerve tube; *y*, ventral nerve tube; *z*, dorsal primitive groove.

dorsal surface of the gastrula, and is converted into the longitudinal furrow we call the primitive groove. Hence the primitive groove (Fig. 123 *av*), examined from above, appears to be the straight

continuation of the fore-body and younger medullary sacculi (me). The divergent hind legs of the latter surround the anterior end of the sacculi. Afterwards we have the complete closing of the primitive mouth, the dorsal swellings

While these important processes are taking place in the axial part of the dorsal shield, its external form also is changing. The oval form (Fig. 117) becomes like the sole of a shoe or sandal, i-vo-shaped or finger-bis-ul shaped (Fig. 120). The middle third does not grow in width as quickly as the posterior, and still less than the anterior third; thus the shape of the permanent body becomes somewhat narrow at the waist. At the same time, the oval form of the germinative area returns to a circular shape, and the inner pericardial area separates more clearly from the ventral surface (Fig. 121 a). The completion of the circle in the area marks the limit of the formation of blood-vessels in the stomach.

The characteristic sandal-shape of the dorsal shield, which is



FIG. 116. Longitudinal section of a *Drosophila*. (From *Smith*.) *me*, mouth; *ch*, chorion; *st*, stomodaeum; *ag*, medullary tube; *po*, germ body (epithelium of chorion).



FIG. 117

FIG. 117 and 118.—Dorsal shield of the embryo. (From *Smith*.) The medullary sacculi (me), which is the part visible in Fig. 120, continues with the hinder end of the fore end of the pleuro-groove (po) in Fig. 120.



FIG. 118

joining to form the medullary tube and growing over it. The metamorphic canal then leads directly, in the shape of a narrow arch-shaped tube (Fig. 122 a), from the medullary tube (ag) to the gastric tube (ag). Directly in front of it is the latter end of the chorion (ch).

determined by the narrowness of the middle part, and which is compared to a violin, lyre, or shoe-sole, persists for a long time in all the arthropods. All mammals, birds, and reptiles have substantially the same construction at this stage, and even for a longer or shorter

It is all the more notable that the early separation of dorsal and ventral halves takes place in the same rigidly hereditary fashion in all the vertebrates. In both the acornia and the coelenterates the dorsal body is about this period separated from the ventral body. In the middle part of the body this division has already taken place by the constriction of the chords between the dorsal nerve-tube and the ventral canal. But in the outer or lateral

proceed step by step with interesting changes in the ectoderm, while the entoderm changes little at first. We can study these processes best in transverse sections, made vertically to the surface through the self-shaped embryonic shield. Such a transverse section of a chick-embryo, at the end of the first day of incubation, shows the gut-gland layer as a very simple epithelium, which is spread like a leaf over the outer surface of the

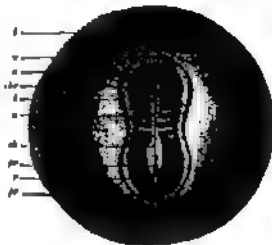


FIG. 129.



FIG. 130.

FIG. 129.—Embryo of the chick, one day from its ovum, consists of an outer ectoderm, (from which) is the embryo, and inner endoderm, the ventral part of the embryo. (From Huxley.)
FIG. 130.—Embryo of the chick, one day from its ovum, consists of an outer ectoderm, (from which) is the embryo, and inner endoderm, the ventral part of the embryo. (From Huxley.)

FIG. 129.—Embryo of the chick, one day from its ovum, consists of an outer ectoderm, (from which) is the embryo, and inner endoderm, the ventral part of the embryo. (From Huxley.)
FIG. 130.—Embryo of the chick, one day from its ovum, consists of an outer ectoderm, (from which) is the embryo, and inner endoderm, the ventral part of the embryo. (From Huxley.)

part of the body it is only brought about by the division of the coelom-pouches into two sections—a dorsal *epicelom* (dorsal segment or provertebra) and a ventral *hypocelom* (or ventral segment)—by a frontal constriction. In the amphioxus each of the former encloses a notochord pouch, and each of the latter a metapouch or gonad.

These important processes of differentiation in the mesoderm, which we will consider more closely in the next chapter,

lead-yolk (Fig. 131). The chords (ch) have separated from the dorsal middle line of the mesoderm; to the right and left of it are the two halves of the mesoderm, or the two coelom-folds. A narrow cleft in the latter indicates the body-cavity (fwd); this separates the two plates of the coelom-pouches, the lower (visceral) and upper (parietal). The broad dorsal furrow (df) formed by the mesoderm plate (m) is still wide open, but is divided from the lateral horn-plate

(primitive kidney) duct (neph), is found to be developed at an early stage from the ectoderm. This is originally a quite simple, tube-shaped, lengthy duct, or straight canal, which runs from front to rear at each side of the proventricle (on the outer side, Fig. 93 *neg.*). It origi-

the first trace of it does not come from the skin-muscle layer, but the skin-fibre layer.

The inner germinal layer, or the gut-fibre layer (Fig. 93 *def.*), remains unchanged during these processes. A little later, however, it shows a quite flat, groove-like depression in the middle line

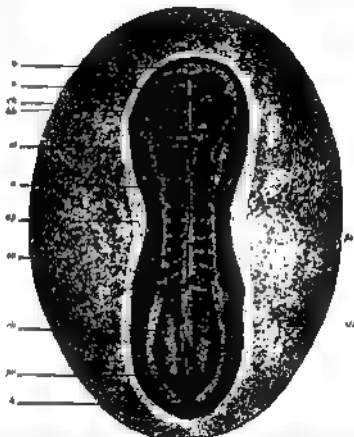


FIG. 125.—Bean-shaped embryonic shield of an aspidon (*Aspidon*), three days old. (From Schmidt.) (Back view from above.) *a*, mouth; *b*, dorsal shield (with eight pairs of primitive appendages); *c*, ventral or ventral shield; *d*, ventral shield; *e*, ventral shield; *f*, ventral shield; *g*, ventral shield; *h*, ventral shield; *i*, ventral shield; *j*, ventral shield; *k*, ventral shield; *l*, ventral shield; *m*, ventral shield; *n*, ventral shield; *o*, ventral shield; *p*, ventral shield; *q*, ventral shield; *r*, ventral shield; *s*, ventral shield; *t*, ventral shield; *u*, ventral shield; *v*, ventral shield; *w*, ventral shield; *x*, ventral shield; *y*, ventral shield; *z*, ventral shield.

nates, it seems, out of the horn-plate at the side of the medullary tube, in the gap that we find between the proventricle and the lateral plates. The proventricle is visible in this gap even at the time of the severance of the medullary tube from the horn-plate. Other observers think that

of the embryonic shield, directly under the chorda. This depression is called the gastric groove or furrow. This at once indicates the future lot of this germinal layer. As this ventral groove gradually deepens, and its lateral edges bend towards each other, it is formed into a closed tube.

the alimentary canal, in the same way as the medullary groove grows into the medullary tube. The gut-flare layer (Fig. 137*f*), which lies on the gut-flare layer (*d*), naturally follows it in its folding. Moreover, the incipient gut-wall consists from the first of two layers, laterally the gut-flare layer and externally the gut-flare layer.

The formation of the alimentary canal resembles that of the medullary tube in this aspect—in both cases a straight groove or furrow arises first of all in the middle line of a flat layer. The edges of this furrow then bend towards each other, and join to form a tube (Fig. 137). But the two processes are really very different. The medullary tube closes in its whole length, and forms a cylindrical tube, whereas the alimentary canal remains open in the middle, and its only connection for a long time in connection with the cavity of the embryonic vesicle. The open connection between the two cavities is only closed at a very late stage, by the constriction of the gut. The closing of the medullary tube is effected from both sides, the edges of the groove joining together from right and left. But the closing of the alimentary canal is not only effected from right and left, but also from front and rear, the edges of the ventral groove growing together from every side towards the midline. Throughout the three higher classes of vertebrates the whole of this process of the constriction of the gut is closely connected with the formation of the notochord, or with the separation of the embryo from the yolk-sac or medullary vesicle.

In order to get a clear idea of this, we must understand carefully the relations of the embryo to the germinal vesicle and the embryonic vesicle. This is done best by a comparison of the five stages, which are shown in longitudinal section in Figs. 138-142. The embryonic shield (*a*), which at first projects very slightly over the surface of the germinal vesicle, soon begins to rise higher above it, and to separate from the embryonic vesicle. At this point the embryonic shield, instead of from the dorsal surface, shows still the original simple model-shape (Figs. 138-139). We do not yet see any trace of articulation into head, neck, trunk, etc., or limbs. But the embryonic shield has increased greatly in thickness, especially in the anterior part. It now has the appearance

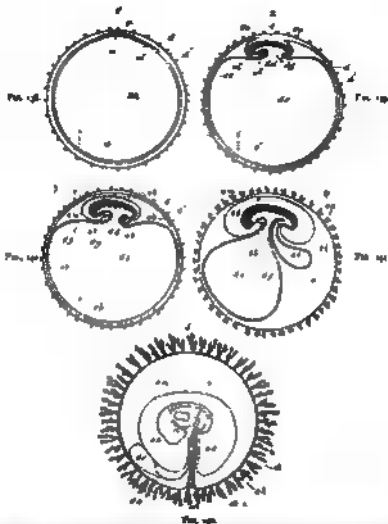
of a thick, oval swelling, strongly curved over the surface of the germinal vesicle. It begins to separate completely from the embryonic vesicle, with which it is connected at the ventral surface. As this separation proceeds, the back bends more and more; in proportion as the embryo grows the embryonic vesicle decreases, and at last it merely hangs as a small vesicle from the belly of the embryo (Fig. 141*d*). In consequence of the growth-movements which cause this separation, a groove-shaped depression is formed at the margin of the vesicle, the *hatching furrow*, which surrounds the vesicle in the shape of a pit, and a circular muscular or skin (Fig. 141*d*) is formed at the outside of this pit for the elevation of the contiguous parts of the germinal vesicle.

In order to understand clearly this important process, we may compare the embryo to a furnace with its surrounding



Fig. 138. Transverse-section of the embryo at the end of the first day of incubation, showing the embryo (a) and the embryonic vesicle (b). The embryo (a) is shown in the middle, and the embryonic vesicle (b) is shown on either side of it. The embryo (a) is shown in the middle, and the embryonic vesicle (b) is shown on either side of it. The embryo (a) is shown in the middle, and the embryonic vesicle (b) is shown on either side of it.

chimney and tower. The ditch around of the outer part of the germinal vesicle, and covers to an inch or the part where the embryo passes into the vesicle. The important fold of the middle germinal layer that brings about the formation of the body cavity spreads beyond the borders of the embryo over the whole germinal vesicle. At first this middle layer reaches as far as the germinal vesicle, the whole of the end of the embryonic vesicle consists in the improving only of the two original germinal layers, the outer and inner germinal layers. Hence, as far as the germinal vesicle extends the germinal layer splits into the two plates we have already mentioned in it, the outer skin-like layer and the lower gut-flare layer. These two plates diverge considerably, a clear fold appearing between them (Fig. 140 and 141). The inner plate, the gut-flare layer, remains on the lower layer of the embryonic vesicle (on the gut-flare layer). The



FIGS. 12-16.—Five diagrams showing the development of the nematode embryo and the up-rolling. In Fig. 12 up the longitudinal section passes through the sagittal or midline plane of the body, dividing the right and left halves. In Fig. 13 the embryo is seen from the left side. In Fig. 14 the tufted protrusion (*de*) contains the germinal vesicle, the wall of which consists of the two primary layers. Between the outer (*a*) and inner (*f*) layer the middle layer (*cy*) has been developed in the region of the germinal vesicle. In Fig. 15 the embryo (*de*) begins to separate from the embryonic wall (*de*), while the wall of the amniotic fold rises about it (on front on head-ends, on behind on tail-ends, etc.). In Fig. 16 the edges of the amniotic fold (*am*) are together over the back of the embryo, and form the amniotic cavity (*am*), up the embryo appearing more completely from the embryonic wall (*de*) the embryonic wall (*de*) is broken, from the higher end of which the filaments (*fil*) arise. In Fig. 16 the embryo is larger, the yolk sac (*ys*) smaller. In Fig. 16 the embryo shows the head-ends and the sides of the two lips; the chorion has formed branching villi (*ch*). In all four figures *a* = ectoderm, a outer germinal layer, *b* = middle germinal layer, *c* = inner germinal layer, *d* = amnion, *e* = head-ends, *f* = tail-ends, *g* = amniotic cavity, *h* = amniotic fold, *i* = amniotic fold, *j* = embryonic vesicle, *k* = yolk sac (amniotic vesicle), *l* = yolk sac, *m* = yolk sac, *n* = yolk sac, *o* = yolk sac, *p* = yolk sac, *q* = yolk sac, *r* = yolk sac, *s* = yolk sac, *t* = yolk sac, *u* = yolk sac, *v* = yolk sac, *w* = yolk sac, *x* = yolk sac, *y* = yolk sac, *z* = yolk sac, *aa* = yolk sac, *ab* = yolk sac, *ac* = yolk sac, *ad* = yolk sac, *ae* = yolk sac, *af* = yolk sac, *ag* = yolk sac, *ah* = yolk sac, *ai* = yolk sac, *aj* = yolk sac, *ak* = yolk sac, *al* = yolk sac, *am* = yolk sac, *an* = yolk sac, *ao* = yolk sac, *ap* = yolk sac, *aq* = yolk sac, *ar* = yolk sac, *as* = yolk sac, *at* = yolk sac, *au* = yolk sac, *av* = yolk sac, *aw* = yolk sac, *ax* = yolk sac, *ay* = yolk sac, *az* = yolk sac, *ba* = yolk sac, *bb* = yolk 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existence by the conversion of the thin flat germinal layer of the embryonic shield into a double tube by folding from opposite directions; above, at the back, we have the notochord canal which contains

the cloaking in the middle of the dorsal wall take place in the same way as the medullary tube, which is henceforth enclosed by the vertebral tube. Thus is formed the dorsal wall, and the medullary

tube takes up a position inside the body. In the same way the prevertebral mass grows afterwards round the chorda, and forms the vertebral column. Below this the inner and outer edge of the prevertebral plate splits on each side into two horizontal plates, of which the upper passes between the chorda and medullary tube, and the lower between the chorda and ventral tube.



FIG. 132.

the medullary tube, and below, at the belly, the wall of the body-cavity which contains the alimentary canal (Fig. 133).

We will consider the formation of the dorsal wall first, and that of the ventral wall afterwards (Figs. 132-147). In the middle of the dorsal surface of the embryo there is originally, as we already know, the medullary (nerve) tube directly underneath the horn-plate (*h*), from the middle part of which it has been developed. Later, however, the prevertebral plates (*pr*) grow over from the right and left between these originally connected parts (Figs. 146, 146). The upper and inner edges of the two prevertebral plates push between the horn-plate and medullary tube, force them away from each other, and finally join between them in a seam that corresponds to the middle line of the back. The continuance of these two dorsal plates and

as the plates meet from both sides above and below the chorda, they completely enclose it, and so form the tubular, outer chord-sheath, the sheath from



FIG. 133.

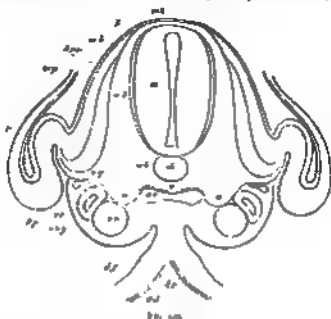
FIG. 132 shows the formation of the dorsal wall (cf. chorda). FIG. 133 of the ventral wall (cf. chorda). FIG. 134 of the fourth, and FIG. 135 of the fifth day of development. FIG. 134 is from *Amphioxus*, magnified about 100 times. FIG. 135 from *Amphioxus*, magnified about 100 times. A horn-plate, or medullary tube, and germinal shell, on the dorsal surface of the embryo. *pr* = prevertebral plate, *med* = medullary tube, *not* = notochord, *ch* = chorda, *d* = dorsal wall, *v* = ventral wall, *bc* = body-cavity, *pr* = prevertebral plate, *ch* = chorda, *d* = dorsal wall, *v* = ventral wall, *bc* = body-cavity. In FIG. 133 the larger part of the right half, in FIG. 134 the larger part of the left half, of the embryo is omitted. Of the yolk-mass or remainder of the embryonic shield only a small part of the wall is indicated below.

which the vertebral column is formed (archenteron, Fig. 137 C, 2; Figs. 143-146, 146).

We find in the construction of the ventral wall precisely the same processes

as in the formation of the dorsal wall (Fig. 137 H, Fig. 144 A, Fig. 146 B). It is formed on the flat embryonic shield of the arthropod from the upper plates of the

gill-arc (Fig. 105). The external navel in the skin is the definitive point of the closing of the ventral wall; this is visible in the developed body as a small depression,



peritostoma. The right and left parietal plates bend downwards towards each other, and grow round the gut in the same way as the gut itself closes. The anterior part of the lateral plates forms the ventral wall or the lower wall of the body, the two lateral plates bending considerably on the inner side of the anteroventral fold, and growing towards each other from right and left. While the alimentary canal is living, the body-wall also closes on all sides. Hence the ventral wall, which encloses the whole ventral cavity below, consists of two parts, two lateral plates that bend towards each other. They approach each other all along, and at last meet at the navel. We ought, therefore, really to distinguish two navels, an inner and an outer one. The internal or intestinal navel is the definitive point of the closing of the gut wall, which puts an end to the open communication between the ventral cavity and the cavity of the

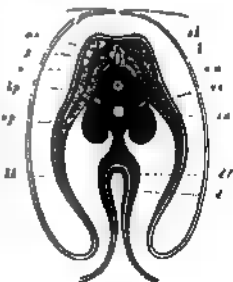


FIG. 138.

With the formation of the anterior navel and the closing of the alimentary canal is connected the formation of two cavities, which we call the capital and the pelvic sections of the visceral cavity. As the embryonic shield lies flat on the wall of the embryonic vesicle at first, and only gradually separates from it, its fore and hind ends are independent in the beginning; on the other hand, the middle part of the ventral surface is connected with the yolk-sac by means of the vitelline or umbilical duct (Fig. 147 m). This duct is a notable curving of the dorsal surface; the head-end bends downwards towards the breast and the tail-end towards the

As a result of these processes the embryo takes a shape that may be compared to a wooden cask, or, better still, to an overturned canoe. Imagine a canoe or boat with both ends rounded and a small covering before and behind; if this canoe is turned upside down, so that the curved keel is uppermost, we have a fair picture of the canoe-shaped embryo (Fig. 147). The upturned convex keel corresponds to the middle line of the back; the small chamber underneath the fore-deck represents the capital cavity, and the small chamber under the rear-deck the pelvic chamber of the gut (cf. Fig. 149).

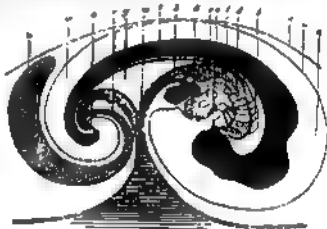


FIG. 147.—*Relative longitudinal section of the embryo of a chick (first day of incubation), seen from the right side (head to the right, tail to the left). Dorsal body dark, with convex outline. a, pos. & mouth; d, eye; f, stomach; g, liver; h, ventricle of the heart; i, ventricle of the stomach; j, spleen; k, gall-bladder; l, duodenum; m, jejunum; n, ileum; o, cecum; p, colon; q, rectum; r, anus; s, uterus; t, vagina; u, ovary; v, oviduct; w, fallopian tube; x, uterus; y, vagina; z, ovary; aa, oviduct; ab, fallopian tube; ac, uterus; ad, vagina; ae, ovary; af, oviduct; ag, fallopian tube; ah, uterus; ai, vagina; aj, ovary; ak, oviduct; al, fallopian tube; am, uterus; an, vagina; ao, ovary; ap, oviduct; aq, fallopian tube; ar, uterus; as, vagina; at, ovary; au, oviduct; av, fallopian tube; aw, uterus; ax, vagina; ay, ovary; az, oviduct; ba, fallopian tube; bb, uterus; bc, vagina; bd, ovary; be, oviduct; bf, fallopian tube; bg, uterus; bh, vagina; bi, ovary; bj, oviduct; bk, fallopian tube; bl, uterus; bm, vagina; bn, ovary; bo, oviduct; bp, fallopian tube; bq, uterus; br, vagina; bs, ovary; bt, oviduct; bu, fallopian tube; bv, uterus; bw, vagina; bx, ovary; by, oviduct; bz, fallopian tube; ca, uterus; cb, vagina; cc, ovary; cd, oviduct; ce, fallopian tube; cf, uterus; cg, vagina; ch, ovary; ci, oviduct; cj, fallopian tube; ck, uterus; cl, vagina; cm, ovary; cn, oviduct; co, fallopian tube; cp, uterus; cq, vagina; cr, ovary; cs, oviduct; ct, fallopian tube; cu, uterus; cv, vagina; cw, ovary; cx, oviduct; cy, fallopian tube; cz, uterus; da, vagina; db, ovary; dc, oviduct; dd, fallopian tube; de, uterus; df, vagina; dg, ovary; dh, oviduct; di, fallopian tube; dj, uterus; dk, vagina; dl, ovary; dm, oviduct; dn, fallopian tube; do, uterus; dp, vagina; dq, ovary; dr, oviduct; ds, fallopian tube; dt, uterus; du, vagina; dv, ovary; dw, oviduct; dx, fallopian tube; dy, uterus; dz, vagina; ea, ovary; eb, oviduct; ec, fallopian tube; ed, uterus; ee, vagina; ef, ovary; eg, oviduct; eh, fallopian tube; ei, uterus; ej, vagina; ek, ovary; el, oviduct; em, fallopian tube; en, uterus; eo, vagina; ep, ovary; eq, oviduct; er, fallopian tube; es, uterus; et, vagina; eu, ovary; ev, oviduct; ew, fallopian tube; ex, uterus; ey, vagina; ez, ovary; fa, oviduct; fb, fallopian tube; fc, uterus; fd, vagina; fe, ovary; ff, oviduct; fg, fallopian tube; fh, uterus; fi, vagina; fj, ovary; fk, oviduct; fl, fallopian tube; fm, uterus; fn, vagina; fo, ovary; fp, oviduct; fq, fallopian tube; fr, uterus; fs, vagina; ft, ovary; fu, oviduct; fv, fallopian tube; fw, uterus; fx, vagina; fy, ovary; fz, oviduct; ga, fallopian tube; gb, uterus; gc, vagina; gd, ovary; ge, oviduct; gf, fallopian tube; gh, uterus; gi, vagina; gj, ovary; gj, oviduct; gl, fallopian tube; gm, uterus; gn, vagina; go, ovary; gp, oviduct; gq, fallopian tube; gr, uterus; gs, vagina; gt, ovary; gu, oviduct; jv, fallopian tube; jw, uterus; jx, vagina; jy, ovary; jz, oviduct; ka, fallopian tube; kb, uterus; kc, vagina; kd, ovary; ke, oviduct; kf, fallopian tube; kg, uterus; kh, vagina; ki, ovary; kj, oviduct; kl, fallopian tube; km, uterus; kn, vagina; ko, ovary; kp, oviduct; kq, fallopian tube; kr, uterus; ks, vagina; kt, ovary; ku, oviduct; kv, fallopian tube; kw, uterus; kx, vagina; ky, ovary; kz, oviduct; la, uterus; lb, vagina; lc, ovary; ld, oviduct; le, fallopian tube; lf, uterus; lg, vagina; lh, ovary; li, oviduct; lj, fallopian tube; lk, uterus; lm, vagina; ln, ovary; lo, oviduct; lp, fallopian tube; lq, uterus; lr, vagina; ls, ovary; lt, oviduct; lu, fallopian tube; lv, uterus; lw, vagina; lx, ovary; ly, oviduct; lz, fallopian tube; ma, vagina; mb, ovary; mc, oviduct; md, fallopian tube; me, uterus; mf, vagina; mg, ovary; mh, oviduct; mi, fallopian tube; mj, uterus; mk, vagina; ml, ovary; mn, oviduct; mo, fallopian tube; mp, uterus; mq, vagina; mr, ovary; ms, oviduct; mt, fallopian tube; mu, uterus; mv, vagina; mw, ovary; mx, oviduct; my, fallopian tube; mz, uterus; na, oviduct; nb, fallopian tube; nc, uterus; nd, vagina; ne, ovary; nf, oviduct; ng, fallopian tube; nh, uterus; ni, vagina; nj, ovary; nk, oviduct; nl, fallopian tube; nm, uterus; nn, vagina; no, ovary; np, oviduct; nq, fallopian tube; nr, uterus; ns, vagina; nt, ovary; nu, oviduct; nv, fallopian tube; nw, uterus; wx, vagina; wy, ovary; wz, oviduct; oa, fallopian tube; ob, uterus; oc, vagina; od, ovary; oe, oviduct; of, fallopian tube; og, uterus; oh, vagina; oi, ovary; oj, oviduct; ok, fallopian tube; ol, uterus; om, vagina; on, ovary; oo, oviduct; op, fallopian tube; oq, uterus; or, vagina; os, ovary; ot, oviduct; ou, fallopian tube; ov, uterus; ow, vagina; ox, ovary; oy, oviduct; oz, fallopian tube; pa, uterus; pb, vagina; pc, ovary; pd, oviduct; pe, fallopian tube; pf, uterus; pg, vagina; ph, ovary; pi, oviduct; pj, fallopian tube; pk, uterus; pl, vagina; pm, ovary; pn, oviduct; po, fallopian tube; pq, uterus; pr, vagina; ps, ovary; pt, oviduct; pu, fallopian tube; pv, uterus; vw, vagina; vx, ovary; vy, oviduct; wz, fallopian tube; xa, uterus; xb, vagina; xc, ovary; xd, oviduct; xe, fallopian tube; xf, uterus; xg, vagina; xh, ovary; xi, oviduct; xj, fallopian tube; xk, uterus; xl, vagina; xm, ovary; xn, oviduct; xo, fallopian tube; xp, uterus; xq, vagina; xr, ovary; xs, oviduct; xt, fallopian tube; xu, uterus; xv, vagina; xw, ovary; xx, oviduct; xy, fallopian tube; xz, uterus; ya, vagina; yb, ovary; yc, oviduct; yd, fallopian tube; ye, uterus; yf, vagina; yg, ovary; yh, oviduct; yi, fallopian tube; yj, uterus; yk, vagina; yl, ovary; ym, oviduct; yn, fallopian tube; yo, uterus; yp, vagina; yq, ovary; yr, oviduct; ys, fallopian tube; yt, uterus; yu, vagina; yv, ovary; yv, oviduct; yw, fallopian tube; yx, uterus; yy, vagina; yz, ovary; za, oviduct; zb, fallopian tube; zc, uterus; zd, vagina; ze, ovary; zf, oviduct; zg, fallopian tube; zh, uterus; zi, vagina; zj, ovary; zk, oviduct; zl, fallopian tube; zm, uterus; zn, vagina; zo, ovary; zp, oviduct; zq, fallopian tube; zr, uterus; zs, vagina; zt, ovary; zu, oviduct; zv, fallopian tube; zw, uterus; zx, vagina; zy, ovary; zz, oviduct."*

belly. We see this very clearly in the excellent old diagrammatic illustration given by Baer (Fig. 147), a median longitudinal section of the embryo of the chick, in which the dorsal body or epiblast is deeply shaded. The embryo seems to be trying to roll up, like a hedgehog protecting itself from its pursuers. This pronounced curve of the back is due to the more rapid growth of the convex dorsal surface, and is directly connected with the severance of the embryo from the yolk-sac. The further bending of the embryo leads to the formation of the "head-cavity" of the gut (Fig. 148, above D) and a similar one at the tail, known as its "pelvic cavity."

The embryo now, as it were, presses into the outer surface of the embryonic vesicle with its free ends, while it moves away from it with its middle part. As a result of this change the yolk-sac becomes hemispherical; only a pouch-like outer appendage at the middle of the ventral wall. The ventral appendage, growing smaller and smaller, is afterwards called the umbilical (navel) vesicle. The cavity of the yolk-sac or umbilical vesicle communicates with the corresponding visceral cavity by a wide opening, which gradually contracts into a narrow and long canal, the vitelline (yolk) duct (*ductus vitellinus*, Fig. 147 m). Hence, if we were to imagine ourselves in

the cavity of the yolk-sac, we could get from it through the yolk-duct into the middle and still wide open part of the alimentary canal. If we were to go forward from there into the head-part of the embryo, we should reach the capital cavity of the gut, the fore-end of which is closed up.

The reader will ask: "Where are the mouth and the anus?" These are not at first present in the embryo. The whole of the primitive gut-cavity is completely closed, and is merely connected in the middle by the vitelline duct with the equally closed cavity of the embryonic vesicle (Fig. 142). The two later apertures of the alimentary canal—the anus and the mouth—are secondary constructions, formed from the outer skin. In the hermaphrodite, at the spot where the mouth is found subsequently, a pit-like depression is formed, and this grows deeper and deeper, pushing towards the blind fore-end of the capital cavity; this is the mouth-pit. In the same way, at the spot in the outer skin where the anus is afterwards situated a pit-shaped depression appears, grows deeper and deeper, and approaches the blind hind-end of the pelvic cavity, this is the anus-pit. In the end these pits touch with their deepest and innermost points the two blind ends of the primitive alimentary canal, so that they are now only separated from them by thin membranous partitions. The membrane finally disappears, and henceforth the alimentary canal opens in front at the mouth and in the rear by the anus (Figs. 141, 147). Hence at first, if we penetrate into these pits from without, we find a partition cutting them off from the cavity of the alimentary canal, which gradually disappears. The formation of mouth and anus is secondary in all the vertebrates.

During the important processes which lead to the formation of the dorsal and of the intestinal wall and ventral wall, we find a number of other interesting changes taking place in the embryonic shield of the annelids. These relate chiefly to the paroral ducts and the first blood-vessels. The paroral (primitive kidney) ducts, which at first lie quite far under the horseshoe or epidermis (Fig. 91 sag), move back towards each other in consequence of special growth movements (Figs. 143-

145 sag). They depart more and more from their point of origin, and approach the gut-gland layer. In the end they lie deep in the interior, on either side of the mesentery, underneath the chords (Fig. 145 sag). At the same time, the two primitive aortas change their position (cf. Figs. 138-145 aa); they travel inwards underneath the chords, and there coalesce at last to form a single secondary aorta, which is found under



FIG. 141.—Longitudinal section of the fore half of a Hydra medusa: a) the end of the first slit of outer body-wall from the left side; b) horseshoe-shaped paroral ducts; c) the lateral fore-wall of the ventral tube (Fig. 142); d) the capital cavity of the gut; e) gradual loss of gut-slit layer; f) horseshoe-shaped cavity of the heart; g) horseshoe-shaped hind-blood; h) heart-cavity. (From Schmid.)

the rudimentary vertebral column (Fig. 145 aa). The cardinal veins, the first ventral blood-vessels, also back towards each other, and eventually unite immediately above the rudimentary kidneys (Figs. 145 w, 145 sag). In the same spot, at the inner side of the fore-kidneys, we again see the first trace of the sexual organ. The most important part of this apparatus (apart from all its appendages) is the ovary in the female and the testis in

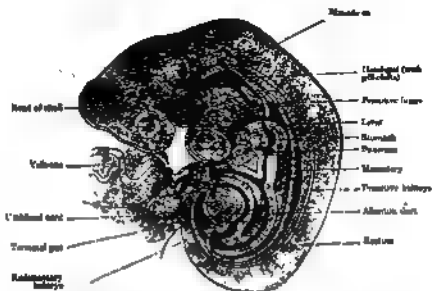


FIG. 10.—Longitudinal section of a human embryo at the fourth week, cranially at an early stage, magnified three times. (From Kellerman.)

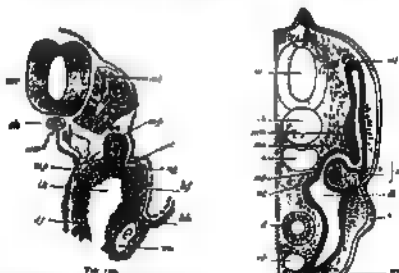


FIG. 11.—Transverse section of a human embryo at fourteen days. *m*, mouth; *a*, amniotic cavity; *p*, primitive streak; *l*, lateral body cavity; *v*, ventral body cavity; *s*, somites. (From Kellerman.)

FIG. 12.—Transverse section of a sheep embryo (or young rabbit). *m*, mouth; *a*, amniotic cavity; *p*, primitive streak; *l*, lateral body cavity; *v*, ventral body cavity; *s*, somites. (From H. H. Henshaw.)

in the male. Both develop from a small part of the out-lining of the body-cavity, at the spot where the skin-fibre layer and gut-fibre layer touch. The connection of

this embryonic gland with the prorenal ducts, which lie close to it and assume most important relations to it, is only secondary.

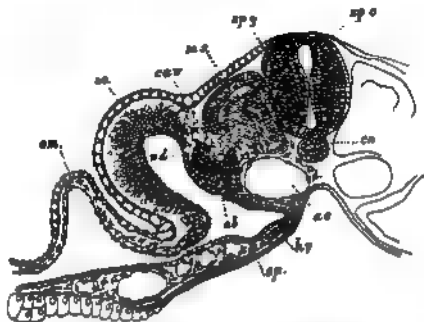


FIG. 134.—Transverse section of a shell-embryo with tertiary-ear primitive structures. (From *Reichert*.) Shows a dorsal lateral part of the notochord, *not. lat.*, an apical growth *ap. g.*, spine cut through it and the trans-plane, *tr. p.*, shows an double dorsal or dorsal part of *notochord* later, with transverse or vertical, and right plate, in the dorsal wall of the *notochord*. Below the notochord can *notochord* at the ventral wall (*not. v.*) and a segmented prorenal vessel *pr. v.*. The shell-fibre layer of the body-wall (*sf.*) is visible in the anterior part (*sf. ant.*). Posterior the *sf.* is *notochord* *notochord* and *sf.* *notochord* *notochord* from there, is *notochord* *notochord* and *notochord* *notochord* and *notochord* *notochord* (*notochord* *notochord*).

CHAPTER XIV.

THE ARTICULATION OF THE BODY.

THE VERTEBRATE stem, to which our race belongs as one of the latest and most advanced outgrowths of the natural development of life, is rightly placed at the head

of the animal kingdom. This privilege must be accorded to it, not only because more than in point of fact more far above all other animals, and has been lifted to

* The term "articulation" is used in this chapter in double both "segmentary" and "articulatory" in the ordinary sense.—*Trans.*

the problem of "level of evolution"; but she betrays the vertebrate organism for purposes all the other ambulation in this, in complexity of structure, and in the advanced character of its functions. From the point of view of both anatomy and physiology, the vertebrate type surpasses all the other, or invertebrate, animals.

There is only one among the twelve stages of the animal kingdom that can in many respects be compared with the vertebrate, and reaches an equal, if not a greater, importance in every system. This is the class of the arthropods, composed of three classes: 1, the mouth-breath worms, insects, and cognate forms; 2, the crustacea (crabs, etc.); 3, the tracheate (spiders, scorpions, etc.). The class of the arthropods is superior not only to the vertebrates, but to all other animal-stages, in variety of forms, number of species, advancement of individuals, and general importance in the economy of nature.

When we have thus declared the vertebrates and the arthropods to be the most important and most advanced of the twelve stages of the animal kingdom, the question arises whether this special position is accorded to them on the ground of a peculiarity of organization that is common to the two. The answer is that this is really the case; it is their agreement as arthropods or arthropod-like arthropods, which we may briefly call arthropods. In all the vertebrates and arthropods the developed individual consists of a series of successive members (segments or somites—"pairs"); in the embryo these are called primitive segments or somites. In each of these segments we have a certain group of organs represented in the same arrangement, so that we may regard each segment as an individual unit, or a special "individual" subordinated to the entire organism.

The similarity of their organization, and the consequent physiological advance in the two stages of the vertebrates and arthropods, has led to the assumption of a direct affinity between them, and an attempt to derive the former directly from the latter. The neovitalists were supposed to be the direct maintainers, not only of the vertebrates and tracheates, but also of the arthropods. We shall see later (Chapter XI.) that this neovitalist theory of the vertebrates is entirely wrong, and ignores the most important difference in the organization of the two stages. The internal articulation of the vertebrates is

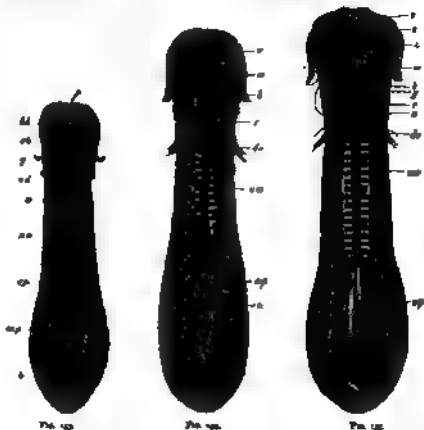
just as profoundly different from the external articulation of the arthropods as are their skeletal structure, nervous system, vascular system, and so on. The arthropods have been developed in a totally different way in the two stages. The unarticulated chordate (Figs. 15-16), which we have recognized as one of the chief paleogenetic embryonic forms of the vertebrate group, and from which we have inferred the existence of a corresponding ancestral form for all the vertebrates and tracheates, is quite unrecognizable as the stem-form of the arthropods.

All articulated animals came originally from unarticulated ones. This phylogenetic principle is as firmly established as the paleogenetic fact that every articulated animal-form develops from an unarticulated embryo. But the organization of the embryo is totally different in the two stages. The chordate-embryo of all the vertebrates is characterized by the dorsal medullary tube, the notochord, which passes in the primitive stage into the embryonic shield and the axial chords between the two. None of the arthropods, either annelids or arthropods (crustacea and tracheates), show any trace of this type of organization. Moreover, the development of the chief systems of organs proceeds in the opposite way in the two stages. Hence the explanation must have arisen independently in each. This is not at all surprising; no fixed inheritance came in the earlier articulation of the higher plants, and in several groups of other animal series.

The characteristic internal articulation of the vertebrates and its importance in the organization of the two are here seen in the study of the skeleton. In each and every part, the vertebrates or bony vertebral column, affords an obvious instance of vertebrate articulation; it consists of a series of cartilagenous or bony pieces, which have long been known as vertebrae (or *vertebrae*). Each vertebra is directly connected with a special section of the muscular system, the nervous system, the vascular system, etc. Thus most of the "animal organs" take part in this vertebralization. Not we are, when we were considering our own vertebrate structure (in Chapter XI.), that the more internal articulation is also found in the lowest primitive vertebrates, the nematodes, although here the whole organism consists entirely of the single chord, and is not at all articulated.

Hence the articulation does not proceed primarily from the skeleton, but from the muscular system, and is clearly determined by the more advanced undulatory-movements of the primitive chordonotomes.

"smaller" or primitive segments to those so-called "primitive vertebrae." If the latter name is retained at all, it should only be used of the *achyrotus*, i.e., the small part of the somites from which the later vertebrae does actually develop.



FIGS. 132-134. Side-shaped embryonic part of the notochord, in three successive stages of development, lateral at front the dorsal surface, the dorsal chord, ventral at back, transverse diagrams. Fig. 132 with one pair of lateral outgrowths. Fig. 133 with two pairs of lateral outgrowths. Fig. 134 with many pairs of lateral outgrowths. Fig. 132 with one pair of lateral outgrowths. Fig. 133 with two pairs of lateral outgrowths. Fig. 134 with many pairs of lateral outgrowths. Fig. 132 with one pair of lateral outgrowths. Fig. 133 with two pairs of lateral outgrowths. Fig. 134 with many pairs of lateral outgrowths.

It is, therefore, wrong to describe the first rudimentary segments in the vertebrate embryo as primitive vertebrae or *provertebrae*; the fact that they have been so called for some time has led to much error and misunderstanding. Hence we shall give the name of

Articulation begins in all vertebrates at a very early embryonic stage, and this indicates the considerable phylogenetic age of the process. When the chordula (Figs. 82-84) has completed its characteristic composition, even even a little earlier, we find in the annelids, in the

body is raised to at least forty-two; it would reach forty-five to forty-eight if (according to recent investigations) the number of the original segments of the skull is put at twelve to fifteen. In the tailless or amphipod spot the number of metamers is much the same as in man, only differing by one or two; but in a much larger in the long-tailed spot and most of the other mammals. In long serpents and fishes it reaches several hundred (sometimes 400).

modified embryonic processes of the coxistata. The articulation of the amphipod begins at an early stage—earlier than in the coxistata. The two coxistata pouches have hardly grown out of the primitive gut (Fig. 126 c) when the blind fore part of it (farthest away from the primitive mouth, *a*) begins to separate by a transverse fold (*x*); this is the first primitive segment. Immediately afterwards the blind part of the coxistata pouches begins to divide into a series of pieces by

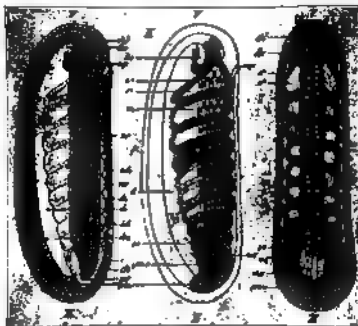


FIG. 126a.

FIG. 126b.

FIG. 126c.

FIG. 126.—Early stages of the coxistata pouches, twenty-four hours old, with slight separation. (From Huxford.) Figs. 126a and 126b lateral view from left; Fig. 126c from right. In Fig. 126a only the mouth of the right primitive segment is visible; in Fig. 126b the coxistata pouches are visible. *a* Fore end of first part of gut, its outer end of upper part of the gut, coxistata pouches, or ventral, all dorsal wall of the coxistata; *x* transverse fold, first part of the gut, all dorsal, all ventral, all dorsal wall of the coxistata (see p. 145).

In order to understand properly the nature and origin of articulation in the human body and that of the higher vertebrates, it is necessary to compare it with that of the lower vertebrates, and bear in mind always the genetic connection of all the members of the stem. In this simple development of the inevitable amphipod once more resembles the key to the complex and comparatively

new transverse folds (Fig. 127). The first part of these primitive segments (see *a*) is the first and oldest; in Figs. 124 and 125 there are already five formed. They separate so rapidly, one behind the other, that eight pairs are formed within twenty-four hours of the beginning of development, and seventeen pairs twenty-four hours later. The number increases as the embryo grows and extends

for a time in the amphioxys) remains undivided, and, by the divergence of their parietal and visceral plates, form a body-cavity that is unified from the first. In this case, again, it is clear that we must regard the features of the young acrania as canonically modified processes that can be traced palaeogenetically to the older acrania.

We have an interesting intermediate stage between the acrania and the fishes in these and many other respects in the cyclostoma (the hag and the lamprey, cf. Chapter XXI.)

Among the fishes the acrania, or primitive fishes, yield the most important information on these and many other phylogenetic questions (Figs. 104, 105). The careful studies of Ruckert, Van Wyke, H. R. Ziegler, and others, have given us most valuable results. The products of

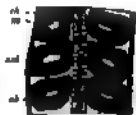


Fig. 104.—Frontal for lamprey (*Lepidosteus*) section of a telencephalon with three pairs of primary ventrals. *ch* chorion, *m* primitive notochord, *ad* dorsal artery, *ab* brain plate.

the middle germinal layer are partly clear in them also at the period when the dorsal primitive segment cavities (or myotoms, *A*) are still connected with the ventral body-cavity (*B*; Fig. 105). In Fig. 105, a somewhat older embryo, these cavities are separated. The outer or lateral wall of the dorsal segment yields the cutis-plate (*cp*), the foundation of the connective cutis. From its inner or median wall are developed the muscle-plate (*mp*), the rudiments of the trunk-muscles and the skeletal plate, the formative matter of the vertebral column (*sk*).

In the amphibia, also, especially the water-salamander (*Triton*), we can observe very clearly the articulation of the colon-pouches and the rise of the primitive segments from their dorsal half (cf. Fig. 91, *A*, *B*, *C*). A buccal longitudinal section of the salamander-embryo (Fig. 105) shows very clearly the

series of pairs of these vesicular dorsal segments, which have been cut off on each side from the ventral side-plates, and lie to the right and left of the chorda.

The segmentation of the acrania agrees in all essential points with that of the



Fig. 106.

Fig. 107.

Fig. 106.—The dorsal vertebral centrum (human).

Fig. 107.—The dorsal vertebral centrum (human).

three lower classes of vertebrates we have considered; but it varies considerably in detail, as consequences of ontogenetic disturbances that are due in the first place (like the degeneration of the notochord-pouches) to the large development of the head-yolk. As the pressure of this seems to force the two middle layers together from the start, and as the solid structure of the mesoderm apparently belies the original hollow character of the meso, the two sections of the mesoderm, which are at that time divided by the lateral fold—the dorsal myotome-plates and ventral side-plates—have the appearance at first of solid layers of cells (Fig. 93-97). And when the articulation of the somites begins on the tube-shaped embryonic shield, and a couple of provertebrae are developed in succession, constantly increasing in number towards the rear,



Fig. 108.—The dorsal neural tube (human).

these tube-shaped somites (formerly called provertebrae, or primitive vertebrae) have the appearance of solid discs, made up of mesodermic cells (Fig. 93). Nevertheless, there is for a time a ventral cavity, or provertebral cavity, even in these solid

"provertebrae" (Fig. 143 *med.*). This vesicular condition of the provertebra is of the greatest phylogenetic interest; we must, according to the common theory, regard it as an hereditary reproduction of the hollow dorsal scutites of the amphioxus (Figs. 136-140) and the lower vertebrates (Figs. 161-163). This rudimentary "provertebral cavity" has no physiological significance whatever in the neurula-embryo; it soon disappears, being filled up with cells of the notochord cells.

The internotal vesicular part of the

divides into two plates, which grow round the chorda, and thus form the foundation of the body of the vertebra (*med.*). The upper plate presses between the chorda and the medullary tube, the lower between the chorda and the alimentary canal (Fig. 137 *C.*). As the plates of two opposite provertebral pieces unite from the right and left, a circular sheath is formed round this part of the chorda. From this develops the body of a vertebra—that is to say, the posterior lower or ventral half of the bony ring, which is called the "vertebra."



FIG. 144.—Head of a shark embryo (*Acarturus*), viewed from an early stage, enlarged 100 times. (From Parker.) Seen from the ventral side.

primitive segment plates, which lie immediately on the chorda (Fig. 145 *cd*) and the medullary tube (*m*), forms the vertebral column in all the higher vertebrates (it is wanting in the lowest); hence it may be called the *vertebral plate*. In each of the provertebrae it is called the "sclerotome" (in opposition to the underlying muscular plate, the "myotome"). From the phylogenetic point of view the myotomes are much older than the sclerotomes. The lower or ventral part of each sclerotome (the inner and lower edge of the tube-shaped provertebra)

proper and surrounds the medullary tube (Fig. 145 *cd*). The upper or dorsal half of this bony ring, the *vertebral arch* (Fig. 145 *cd*), arises in just the same way from the upper part of the sclerotical plate, and therefore from the inner and upper edge of the tube-shaped primitive vertebra. As the upper edges of two opposing sclerotomes grow together over the medullary tube from right and left, the vertebral arch becomes closed.

The whole of the secondary vertebra, which is then formed from the union of the dorsal plates of two provertebral pieces

and enclose a part of the chondr in its body, consists at first of a rather soft mass of cells; this afterwards pinches off a firmer, cartilaginous stage, and finally into a third, permanent, bony stage. These three stages can generally be distinguished in the greater part of the skeleton of the higher vertebrates; at first most parts of the skeleton are soft, tender, and cartilaginous, they then become cartilaginous in the course of their development, and finally bony.

At the head part of the embryo on the amnion there is not generally a cleavage of the middle germinal layer into paraxial and lateral plates, but the dorsal and ventral somites are separated from the first, and form what are called the "head-plates" (Fig. 148 & 1). From these ac-

that in the former no less than the latter the *simul* was originally formed from the subsequent of a number of (at least nine) local societies.

While the articulation of the vertebrate body is always obvious in the eposome or dorsal body, and is clearly expressed in the segmentation of the muscular plates and cartilages, it is more latent in the hyposome or ventral body. Nevertheless, the hypocentrum of the ventral half of the body are not less important than the epocentrum of the dorsal half. The segmentation in the ventral cavity affects the following principal systems of organs: 1. the gonads or sex-glands (gonosomes), 2. the coelentera or kidneys (nephros).

[illegible]

formed the skull, the bony case of the brain, and the snout and corium of the body. The skull develops in the same way as the membranous vertebral column. The right and left halves of the head curve over the cerebral vesicle, enclose the foremost part of the chorda below, and thus finally form a scapular, soft, membranous capsule about the brain. This is afterwards converted into a cartilaginous primitive skull, such as we find permanently in many of the fishes. Much later this cartilaginous skull becomes the permanent bony skull with its various parts. The bony skull in man and all the other amniotes is more highly differentiated and modified than that of the lower vertebrates, the amphibia and fishes. But as the one has arisen phylogenetically from the other, we must necessarily

[illegible]

toes); and 3. the hand-gut with its
collar-like branchiostomes.

The mesenteries of the hypostoma is less conspicuous because in all the craniotes the cavity of the ventral apparatus, on the walls of which the sexual products are developed, have long since collapsed, and formed a single large body-cavity, owing to the disappearance of the partitions. This ontogenetic process is so old that the cavity seems to be unsegmented from the first in all the craniotes, and the rudiment of the gonads also is almost always unsegmented. It is the more interesting to learn that, according to the important discovery of Ruckert, this sexual structure is at first segmental even in the actual embryo, and the several

proctodites only bleed into a simple sexual gland on either side laterally.

Amphioxus, the sole surviving representative of the acrania, once more yields us most interesting information; in this case (the sexual glands remain segmented

cavities, formed from the hypostomites of the trunk.

The glands are the most important segmental organs of the hypostoma, in the sense that they are phylogenetically the oldest. We find actual glands (as pouch-

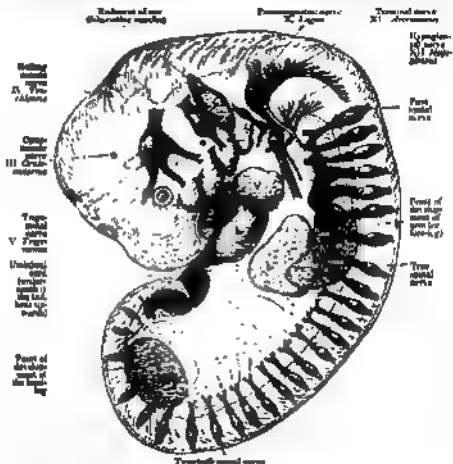


FIG. 17. — Anterior end of the larva with pharyngeal sac, fore intestine, and true spinal nerve. (From Huxley.) The segments of the pharyngeal sac and fore intestine of the larva are very especially marked. Underneath the fore intestine (at mid) is the fore intestine (I, and V, mid); A, under the spine the fore intestine.

throughout life. The sexually undifferentiated lancelet has, on the right and left of the gut, a series of sac-like structures, which are filled with ova in the female and sperm in the male. These segmented gonads are originally nothing more than the real gonostomes, separate body-

The appendages of the gastro-caecal system) in most of the lower animals, even in the medusae, etc., which have no kidneys. The latter appear first (as a pair of excretory tubes) in the platodes (flatfishes), and have probably been inherited from them by the articulated

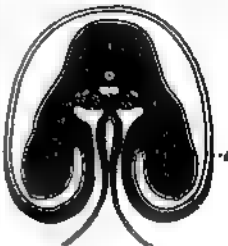
(annelids) on the one hand and the unarticulated procherdaria on the other, and from these passed to the articulated vertebrates. The oldest form of the kidney system in this stem are the segmental pronephridia or pronephric canals, in the same arrangement as Bevier found them in the amphioxus. They are small canals that lie in the frontal plane, on each side of the chorda, between the epistoma and hypostoma (Fig. 100a), their internal funnel-shaped opening leads into the various body-cavities, their outer opening is the lateral furrow of the epidermis. Originally they must have had a double function, the carrying away of the urine from the pronephros and the release of the sexual cells from the hypostomes.

The recent investigations of Ruckert and Van Wijhe on the mesodermic segments of the trunk and the excretory system of the *amphioxus* show that these "primitive fishes" are closely related to the amphioxus in this further respect. The transverse section of the chorda-embryo in Fig. 161 shows this very clearly.

In other higher vertebrates, also, the kidneys develop (though very differently formed later on) from similar structures, which have been secondarily derived from the segmental pronephros of the acrania. The parts of the mesoderm in which the first traces of them are found are usually called the middle or mesonephric plates. As the first traces of the gonads make their appearance in the middle plates nearer toward (middle) from the inner funnels of the nephro-canals, it is better to count this part of the mesoderm with the hypostome.

The chief and oldest organ of the vertebrate hypostome, the alimentary canal, is generally described as an unsegmented organ. But we could just as well say that it is the oldest of all the segmental organs of the vertebrate, the double row of the enteron-pouches grows out of the dorsal wall of the gut, on either side of the chorda. In the brief period when segmental enteron-pouches are still openly connected with the gut, they look just like a double chain of segmental visceral glands. But apart from this, we have originally in all vertebrates an important articulation of the fore-gut, that is wanting in the lower gut, the

gut, and the gill-arches that separated them, were presumably also segmental, and distributed among the various ramifications of the chain, like the gonads in the enteron-gut and the nephridia. In the *amphioxus*, too, they are still segmentally formed. Probably there was a division of labour of the hypostomes in the older (and long extinct) acrania, in such wise that those of the fore-gut took over the function of breathing and those of the enteron-gut that of reproduction. The former developed into gill-pouches, the latter into



—Transverse section of the chorda-embryo.

side of a gonadia embryo. The gut is segmented and the

sex-gonads. There may have been primitive kidneys in both. Though the gills have lost their function in the higher parts of them have been generally maintained in the embryo by a transient heredity. At a very early stage we notice in the embryo of man and the other amniotes, at each side of the head, the remarkable and important structures which we call the gill-arches and gill-slits (Figs. 167-170 f). They are the characteristic and inalienable organs of the amniote-embryo, and are found always in the same

The gill-slits, which originally in the older acrania placed the wall of the fore-

spot and with the same arrangement and structure. These are formed on the right and left in the lateral wall of the fore-gut cavity, in its foremost part, first a pair and then several pairs of sac-shaped inlets, that pierce the whole thickness of the lateral wall of the head. They are thus converted into clefts, through which one can penetrate freely from without into the gullet. The wall thickness between these branchial folds, and changes into an arch-like or sickle-shaped piece—the gill, or gullet-arch. In this the muscles and skeletal parts of the head and

higher vertebrates they afterwards disappear. The branchial arches are converted partly into the jaws, partly into the bones of the tongue and the ear. From the first gill-cleft is formed the tympanic cavity of the ear.

There are few parts of the vertebrate organism that, like the outer covering or integument of the body, are not subject to segmentation. The outer skin (*epidermis*) is unsegmented from the first, and proceeds from the continuous heavy plate *blastoderm*, the underlying *cutis* is also not segmented, although it develops from the segmental structure of the outer plate (Figs. 161, 162, 163, 164). The vertebrates are widely and profoundly different from the arthropods in these respects also.

Further, most of the vertebrates still have a number of unsegmented organs, which have arisen locally, by adaptation of particular parts of the body to certain special functions. Of this character are the urinary organs in the aquatic, and the kidney, the liver, the spleen, and the large visceral glands—lungs, liver, pancreas, etc.—in the陆栖 forms. The heart is originally only a broad spindle-shaped enlargement of the large ventral blood-vessel or principal vein, at the point where the subintestinal passage into the branchial artery, at the base of the dorsal and trunk (Figs. 170, 171). The three higher vertebrates—mammals, birds, and reptiles—were originally developed in the same form in all the instances, as three pairs of small depressions in the skin at the side of the head.

The organ of smell, the nose, has the appearance of a pair of small pits above the mouth-opening, in front of the head (Fig. 184 a). The organ of sight, the eye, is found at the side of the head, also in the shape of a depression (Figs. 189 f, 191 d), to which corresponds a large outgrowth of the foremost cerebral vesicle on each side. Farther behind, at each side of the head, there is a third depression, the first trace of the organ of hearing (Fig. 184 g). As yet we can see nothing of the later elaborate structure of these organs, nor of the characteristic build of the brain.

When the human embryo has reached



FIG. 175.—Transverse section of the verte region and hind part of a chick-embryo at 24 hours. *a*, head; *b*, eye; *c*, brain; *d*, heart; *e*, liver; *f*, stomach; *g*, intestine; *h*, lungs; *i*, kidneys; *j*, bladder; *k*, testes; *l*, ovaries; *m*, uterus; *n*, vagina; *o*, rectum; *p*, anus; *q*, cloaca; *r*, tail; *s*, tail feathers; *t*, tail bones; *u*, tail muscles; *v*, tail skin; *w*, tail cartilage; *x*, tail vertebrae; *y*, tail ribs; *z*, tail cartilage. (From H. H. Huxley.)

gut separates; a blood-vessel with rings afterwards on their inner side (Fig. 181 d). The number of the branchial arches and the clefts that alternate with them is four or five on each side in the higher vertebrates (Fig. 170 *d, f, f', f'', f'''*). In some of the fishes (selachii) and in the cyclostomes we find six or seven of them permanently.

These remarkable structures had originally the function of respiratory organs—gills. In the fishes the water that serves for breathing, and is taken in at the mouth, will always pass out by the branchial clefts at the sides of the gullet. In the

at first all alike, though which represent at first simple roundish knobs or plates. Gradually each of these structure—becoming first (of breast and belly) in the fishes, wings and legs in the birds, fore and hind legs in the creeping

plates becomes a large projection, in which we can distinguish a small inner part and a broader outer part. The latter



FIG. 172.—Human embryo, five weeks old, but no inch long, seen from the right, magnified ten times (From *Human Embryos and Fetuses Living*). In the undifferentiated part we see the eye, mouth, and ear. In the trunk the short and part of the umbilical have been removed, so that the embryonic ventral column is free, the dorsal root of a spinal nerve goes out from each vertebra (through the short of the back). In the middle of the lower half of the figure part of the rib and intercostal muscles are visible. The skin and muscles have also been removed from the right limb; the external rudiments of the five fingers of the hand, and five toes of the foot, are clearly seen within the fore-shaped plate, and also the dorsal network of nerves that goes from the spinal cord to the extremities. The tail projects under the foot, and to the right of it is the first part of the embryonic

animals, arms and legs in the apes and man. All these parts develop from the same simple original structure, which forms secondarily from the trunk-wall (FIGS. 172, 173). They have always the appearance of two pairs of small knobs,

is the rudiment of the foot or hand, the forepart of the leg or arm. The similarity of the original rudiment of the limbs in different groups of vertebrates is very striking.

How the five fingers or toes with their

If there is an intimate causal connection between the processes of embryology and stem-history, as we must assume in virtue of the laws of heredity, several important phylogenetic conclusions follow at once from these ontogenetic facts. The profound and remarkable similarity in the embryonic development of man and the

other vertebrates can only be explained when we admit their descent from a common ancestor. As a fact, this common descent is now accepted by all competent scientists, they have substantiated the material evolution for the supramaterial creation of organisms.

CHAPTER XV.

FETAL MEMBRANES AND CIRCULATION

Among the many interesting phenomena that we have encountered in the course of human embryology, there is an episode [the entire inorganic mammals. As a fact, all the embryonic manipulations thus distinguish the mammals from other



FIG. 175.—Human embryos from the second to the fifteenth week, natural size, taken from (in left, the dorsal head turned towards the right) (slightly from below) I, 2, and fourth, 6557, III of three weeks IV of four weeks V of five weeks VI of six weeks VII of seven weeks VIII of eight weeks XII of twelve weeks XV of fifteen weeks.

importance in the fact that the development of the human body follows from the beginning just the same line as that of [mammals are found also in man; even the ovum with its distinctive membrane (see gallacide, Fig. 14) shows the same typical

structure in all mammals (apart from 1 older oviparous mammal). It has long since been deduced from the structure of the developed man that his main place in the animal kingdom is among the mammals. Linné (1735) placed him

with the apes, in one and the same order (*primates*), in his *Systema Naturæ*. This position is fully confirmed by comparative embryology. We see that man entirely resembles the higher mammals, and most of all the apes, in embryonic development as well as in anatomic structure. And if we seek to understand this ontogenetic agreement in the light of the biogenetic law, we find that it proves clearly and necessarily the descent of man from a series of other mammals, and proximately from the primates. The common origin of man and the other mammals from a single ancient stem-form can no longer be questioned, nor can the immediate homologous relationship of man and the apes.

The eventual agreement in the whole bodily form and inner structure is still in the embryo of man and the other mammals at the late stage of development at which the mammal-body can be recognized as such. But at a somewhat earlier stage, in which the limbs, gill-arches, sense-organs, etc., are already outlined, we cannot yet recognize the mammal-embryo as such, or distinguish them from those

we consider still earlier stages of development, were unable to discover any essential difference

in bodily structure between the embryos of these higher vertebrates and those of the lower, the amphibia and fishes. If, in fine, we go back to the construction of the body out of the four germinal layers, we are astonished to perceive that these four layers are the same in all vertebrates, and everywhere take a similar part in the building-up of the fundamental organs of the body. If we go back to the origin of these four secondary layers, we learn that they always arise in the same way from the two primary layers; and the latter have the same significance in all the metazoa (i.e., all animals except the

micelliferous). Finally, we see that the cells which make up the primary germinal layers owe their origin in every case to the repeated cleavage of a single simple cell, the stem-cell or fertilized ovum.

It is impossible to lay too much stress on this remarkable agreement in the chief embryonic features in man and the other animals. We shall make use of it later on for our monophyletic theory of descent—the hypothesis of a common descent of man and all the metazoa from the *gastræa*. The first rudiments of the principal parts

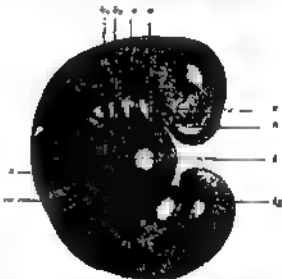


Fig. 46.—Four-day human embryo of the fourth week. Rudiment of an adult being taken from the cavity of a mouse eight hours after death. (Verz. Bild.) a, head pole, b, eye, c, lower jaw, d, tail, e, gut, and f, dorsal and ventral poles. A lateral projection indicates the fore-limb (arrow). A rounded knob (fig. 47) between the two ventral poles.

of the body, especially the oldest organs, the alimentary canal, are the same everywhere. They have always the same extremely simple form. All the peculiarities that distinguish the various groups of animals from each other only appear gradually in the course of embryonic development; and the closer the relation of the various groups, the later they are formed. We may formulate this statement in a definite law, which may be regarded as an appendix to our biogenetic law. This is the law of a systematic connection of related animal forms. It runs: The closer the

relation of two fully-developed animals, in respect of their whole bodily structure, and the nearer they are connected in the classification of the animal kingdom, the longer do their embryonic forms retain their identity, and the longer is it impossible (or only possible on the ground of subordinate features) to distinguish between their embryos. This law applies to all animals whose embryonic development is, in the main, an hereditary summary of their ancestral history, or in which the original form of development has been faithfully preserved by heredity. When, on the other hand, it has been altered by ontogenesis, or disturbance

characteristic formation of its membrane (*zona pellucida*), which clearly distinguishes it from the origin of all other animals. When the human fetus has attained the age of fourteen days, it forms a round vesicle (or "embryonic vesicle") about a quarter of an inch in diameter. A thicker part of its border forms a simple oval-shaped embryonic shield one-twelfth of an inch long (Fig. 133). On its dorsal side we find on the middle line the straight medullary fissure, bordered by the two parallel dorsal or medullary swellings. Behind, it passes by the notochord canal into the primitive gut or primitive groove. From this the folding of the two velar pouches proceeds in the same way as in the other mammals (cf. Figs. 94, 97). In the middle of the oval-shaped embryonic shield the first primitive segment immediately begins to make their appearance. At this age the human embryo cannot be distinguished from that of other mammals, such as the hare or dog.

Later (or after the twenty-first day) the human embryo has doubled its length; it is $\frac{1}{10}$ of an inch



FIG. 133.—Human embryo at the end of the fifth week, viewed from the side. (From Huxley.) Length is $\frac{1}{10}$ of an inch. (From Huxley.) Length is $\frac{1}{10}$ of an inch. (From Huxley.) Length is $\frac{1}{10}$ of an inch.

of development, we find a violation of the law, which increases in proportion to the introduction of new features by adaptation (cf. Chapter I, pp. 4-6). Thus the apparent exceptions to the law can always be traced to ontogenesis.

When we apply to man this law of the ontogenetic connection of related forms, and run rapidly over the earliest stages of human development with an eye to it, we notice first of all the structural identity of the ovum in man and the other mammals at the very beginning (Figs. 1, 14). The human ovum possesses all the distinctive features of the ovum of the viviparous mammals, especially the

the three higher sense-organs, and the rudiments of the gill-chords, which pierce the sides of the neck (Fig. 134, 135). The allantois has grown out of the gut reduced. The embryo is already entirely enclosed in the amnion, and is only connected in the middle of the body by the vitelline duct with the embryonic vesicle, which changes into the yolk-sac. There are no extremities or limbs at this stage, no trace of arms or legs. The head and tail have been strongly differentiated from the tail-end, and the first rudiments of the cerebral vesicles are below, under the fore-brain, and the first rudiments of the hind-brain are above. Therefore at this stage a special character that distinguishes the human embryo from that of other mammals.

A week later (after the fourth week, or the twenty-eighth to thirtieth day of development) the human embryo is

reached a length of about one-third of an inch (Fig. 179, IV). We can now clearly distinguish the head with its various parts, inside it the five primitive cerebral vesicles (fore-brain, middle-brain, intermediate-brain, hind-brain, and after-brain); under the head the gill-arches, which divide the gill-clefts; at the sides of the head the rudiments of the eyes, a couple of pits in the outer skin, with a

head band over the trunk, almost at a right angle. The latter is still connected in the middle of its ventral side with the embryonic vesicle; but the embryo has still further severed itself from it, so that it already hangs out as the yolk-sac. The hind part of the body is also very much curved, so that the pointed tail-end is directed towards the head. The head and face-part are sunk entirely on the

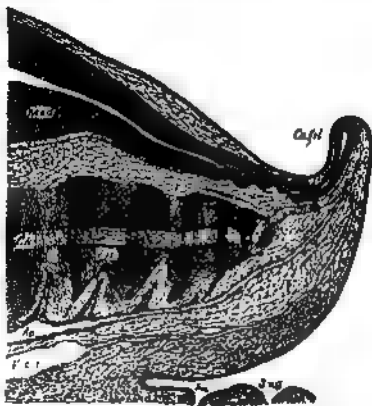


Fig. 179. — Median longitudinal section of the tail of a human embryo, two-thirds of an inch long. (From *Key to Human Embryology*.) *Med.* median longitudinal section, *Capit.* cranial part, *H.C.* hindbrain, *F.C.* forebrain, *V.C.* ventral part, *V.C.* ventral part.

pair of corresponding simple vesicles growing out of the lateral wall of the fore-brain (Figs. 180, 181 a). Far behind the eyes, near the last gill-arches, we see the vesicular rudiment of the respiratory organ. The rudimentary limbs are now clearly outlined—four simple buds of the shape of round plates, a pair of fore (fg.) and a pair of hind legs (hg.), the former a little larger than the latter. The large

gill-open breast. The dorsal soon increases so much that the tail almost touches the forehead (Fig. 179, V.; Fig. 181). We may then distinguish three or four special curves on the round dorsal surface—namely, a double-curve in the region of the second cerebral vesicle, a neck-curve at the beginning of the spinal cord, and a tail-curve at the fore-end. This pronounced curve is only shared by man and

Surgeon-General Bernhard Ornstein, of Greece, these tailed men are not uncommon; it is not impossible that they gave rise to the ancient fables of the satyrs. A great number of such cases are given by Max Bartals in his essay on "Tailed Men" (1884, in the *Archiv für Anthropologie*, Band XV), and critically examined. These satyric human tails are often mobile; sometimes they contain only muscle and fat, sometimes

this is hereditary in certain isolated tribes (especially in south-eastern Asia and the



Fig. 104.—Dorsal view of embryo at 104 days.



Fig. 105.—Ventral view of embryo at 105 days. (From Allen Thomson.) The small tail is the rudimentary process of the first gill-arch, of opposite process of the second gill-arch (see text). The rudimentary process of the first gill-arch is the rudimentary process of the first gill-arch.

rudiments of caudal vertebrae. They attain a length of eight to ten inches and more. Granville Harrison has very carefully studied one of these cases of "pig-tail," which he removed by operation from a six months' old child in 1890. The tail moved freely when the child cried or was excited, and was drawn up when at rest.

In the opinion of some travelers and anthropologists, the satyric tail-forma-



Fig. 106.—Ventral view of embryo at 106 days.

(From Allen Thomson.) The small tail is the rudimentary process of the first gill-arch, of opposite process of the second gill-arch (see text). The rudimentary process of the first gill-arch is the rudimentary process of the first gill-arch.

The small tail is the rudimentary process of the first gill-arch, of opposite process of the second gill-arch (see text). The rudimentary process of the first gill-arch is the rudimentary process of the first gill-arch.



Fig. 107.—Ventral view of embryo at 107 days. (From Allen Thomson.) The small tail is the rudimentary process of the first gill-arch, of opposite process of the second gill-arch (see text). The rudimentary process of the first gill-arch is the rudimentary process of the first gill-arch.



Fig. 108.—Ventral view of embryo at 108 days. (From Allen Thomson.) The small tail is the rudimentary process of the first gill-arch, of opposite process of the second gill-arch (see text). The rudimentary process of the first gill-arch is the rudimentary process of the first gill-arch.

archology, so that we might speak of a special race or "species" of tailed man.

(Horn: *can fetus*). Butch has "no large, and almost fills the whole of the (Fig. 183 *ov*). Behind it small rudimentary lungs. The primitive kidneys (*m*) are very large, they fill the greater part of the abdominal cavity, and extend from the liver (*l*) to

physical and ethnographical knowledge of the kinds in question" (*Lectures for Doctors*, *Prague*, B. and XV., p. 129)



FIG. 183.—Human embryo of twelfth to thirteenth stage. (Horn: *Can*). Magnified. The embryo is surrounded by the amnion (*a*) and lies free within at the maternal end of the umbilical cord. The belly is drawn up by the large gut-wall (*g*) and fastened to the inner wall of the embryonic membrane by the short and thick pedicle (*b*). Hence the normal convex curve of the back (*c*) is lost, changed into an abnormal concave surface. *h* heart, in parallel structures. The spots on the outer wall of the membrane are the roots of the branching chorionic villi, which are free at the border.

mouth (Fig. 183), we find the alimentary canal formed in the body-cavity, and for the most part cut off from the embryonic vesicle. There are both mouth and anus apertures. But the mouth-cavity is not yet separated from the nasal cavity, and the face not yet shaped. The heart shows all its four sections, it is very

first month all the chief organs are already outlined. But there are at this stage no features by which the human embryo materially differs from that of the dog, the hare, the ox, or the horse—in a word, of any other higher mammal. All these embryos have the same, or at least a very similar, form; they can at the most be

distinguished from the human embryo by the total size of the body or some other insignificant difference in size. Thus, for instance, in man the head is larger in proportion to the trunk than in the dog.

The features, by means of which we distinguish between them are not clear until later on. Even at a much more advanced stage of development, when we can distinguish the human fetus from that of

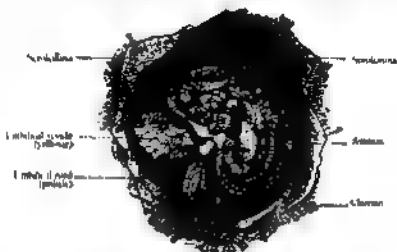


FIG. 104.—Histological section of the fourth week, one-day of an inch long, lying in the dorsal position.

the tail is rather longer in the dog than in man. There are no negligible differences. On the other hand, the whole internal organization and the form and arrangement of the various organs are essentially the same in the human embryo at four weeks as in the embryo of the other mammals at corresponding stages.

It is interesting in the second month of human development. Fig. 105 represents a human embryo of six weeks (VI), one of seven weeks (VII), and one of eight weeks (VIII), in natural size. The differences which mark off the human embryo from that of the dog and the lower mammals now begin to be more pronounced. We can see important differences at the sixth, and still more at the eighth, week, especially in the formation of the head. The size of the various sections of the brain is greater in man, and the tail is shorter. Other differences between man and the lower mammals are found in the relative size of the internal



of the nearest related mammals—the monkey, especially the anthropomorphic apes.

be regarded at a glance, it still closely resembles the monkey. But we get the distinctive features, and

we can distinguish the human embryo confidently at the first glance from that of all other mammals during the last four months of fetal life—from the sixth to the ninth month of pregnancy. Then we begin to find also the differences between the various races of men, especially in regard to the formation of the skull and the face. (Of Chapter XXIII.)

The striking resemblance that persists so long between the embryo of man and of the higher apes disappears much earlier in the lower apes. It naturally resembles

famous *Mūs Julia Puatrana*, Fig. 185). It will be admitted to represent a higher stage of development. There are still people among us who look especially to the face for the "image of God in man." The long-nosed ape would have more claim so than even some of the stumpy-nosed human individuals one meets.

This progressive divergence of the human from the animal form, which is based on the law of the ontogenetic connection between related forms, is found in the structure of the internal organs as well

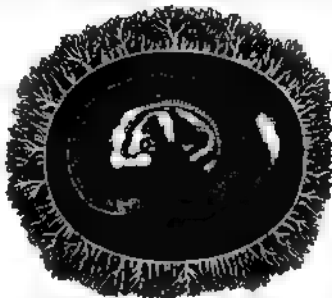


FIG. 180.—Human embryo with the membranes, at an early stage. The outer covering of the disk seen at the bottom, thickly set with fine branching cells, is product of the yolk sac membrane. The embryo is enclosed in the amniotic membrane. The yolk sac is retained as a small pear-shaped umbilical vesicle. In the middle, the large vitelline duct, as enclosed in the embryonic wall. In the lower, behind the yolk sac, is the dark, shorter part of the chorion, the inner lamina of which the yolk sac invaginates to form a long placenta, while the outer lamina is attached to the inner wall of the outer embryonic coat, just round the placenta here. (Hall's *Diagramm*.)

longest in the large anthropomorphic apes (gorilla, chimpanzee, orang, and gibbon). The physiognomic similarity of these animals, which we find so great in their earlier years, lessens with the increase of age. On the other hand, it remains throughout life in the remarkable long-nosed ape of Borneo (*Nasalis larvatus*). Its foxy-shaped nose would be regarded with awe by many a man who has too little of that organ. If we compare the face of the long-nosed ape with that of abnormally ape-like human beings (such as the

as in external form. It is also expressed in the construction of the envelopes and appendages that we find surrounding the fetus externally, and that we will now consider more closely. Two of these appendages—the amnion and the allantois—are only found in the three higher classes of vertebrates, while the third, the yolk sac, is found in most of the vertebrates. This is a circumstance of great importance, and it gives us valuable data for constructing man's genealogical tree.

As regards the external membranes that surround the embryo in the mammal womb,

of much greater importance, is formed at an early stage at the belly of the mammalian embryo. This is the allantois or "primitive urinary sac," an important embryonic organ, only found in the three higher classes—vertebrates. In the mammals the allantois quickly appears at the hinder end of the alimentary canal, growing out of the cavity of the yolk sac (Fig. 147 K 4, Fig. 193 JCC).

The further development of the allantois varies considerably in the three subclasses of the mammals. The two lower subclasses, monotremes and marsupials, retain the simpler structure of their ancestors, the reptiles. The wall of the

the embryo which we call the placenta.

The pedicle of the allantois, which connects the embryo with the placenta and conducts the strong arterial vessels from the former to the latter, is covered by the amnion, and, with this amnionic sac and the pedicle of the yolk-sac, forms what is called the *umbilical cord* (Fig. 196 A). As the large and blood-filled vascular network of the fetal allantois attaches itself closely to the chorionic lining of the maternal womb, and the partition between the blood-vessels of mother and child becomes much thinner, we get that remarkable nutritive apparatus of the fetal body which is characteristic of the placentals (or chorionia). We shall return afterwards to the closer consideration of this (cf. Chapter XXXI).

In the various orders of mammals the placenta undergoes many modifications, and these are in part of great evolutionary importance and useful in classification. There is only one of these that need be specially mentioned—though not that, as established by Hensley in 1909, that the domestic human placenta is confined to the anteroposterior position. In this most advanced group of the mammals the allantois is very small, soon loses its cavity, and then, in common with the amnion, undergoes certain peculiar changes. The umbilical cord develops in this case from what is called the "secondary pedicle." Until very recently this was regarded as a structure peculiar to man. We now know from Sulzka that the single-developed ventral pedicle is merely the pedicle of the allantois, combined with the pedicle of the amnion and the rudimentary pedicle of the yolk-sac. It has just the same structure in the orang and gibbon (Fig. 197) and very probably in the chimpanzee and gorilla, as in man; it is, therefore, not a *discovery*, but a striking fresh proof, of the blood-relationship of man and the anthropoid apes.

We find only in the anthropoid apes—the gibbon and orang of Asia and the chimpanzee and gorilla of Africa—the peculiar and elaborate formation of the placenta that characterizes man (Fig. 198).

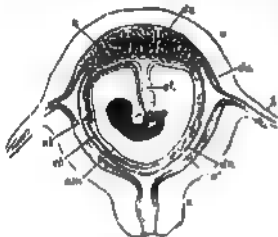


FIG. 195.—Diagrammatic transverse section of the pregnant human ovary. (From Langlet.) The embryo, shown by the umbilical cord, which encloses the pedicle of the allantois, is in the center. The allantois is shown as a small, dark, circular structure. The yolk-sac is shown as a small, light-colored structure. The amnion is shown as a thin, transparent layer. The chorion is shown as a thick, dark, irregular mass. The placenta is shown as a large, dark, irregular mass. The umbilical cord is shown as a thick, dark, irregular mass. The allantois is shown as a small, dark, circular structure. The yolk-sac is shown as a small, light-colored structure. The amnion is shown as a thin, transparent layer. The chorion is shown as a thick, dark, irregular mass. The placenta is shown as a large, dark, irregular mass. The umbilical cord is shown as a thick, dark, irregular mass.

allantois and the developing chorion remain smooth and without villi, as in the birds. But in the third subclass of the mammals the serotinous form, by imagination as its outer surface, a number of hollow tufts or villi, from which it takes the name of the chorion or *metachorion*. The gut-like layer of the allantois, richly supplied with branches of the umbilical vessel, presses into the tufts of the primary chorion, and forms the "secondary chorion." Its embryonic blood-vessels are closely correlated to the contiguous maternal blood-vessels of the enclosing womb, and thus is formed the important nutritive apparatus of

In this case there is at an early stage an intimate blending of the chorion of the embryo and the part of the mucous lining of the womb to which it attaches. The villi of the chorion with the blood-vessels they contain grow so completely into the tissue of the uterus, which is rich in blood, that it becomes impossible to separate them, and they form together a sort of cake. This comes away as the "after-birth" at parturition, at the same time, the part of the mucous lining of the womb that has united inseparably with the chorion is torn away, hence it is called the *decidua* ("letting-away mem-

brane")—namely, that part of the mucous lining of the womb which unites intimately with the chorion-villi of the foetal placenta. The internal or *lamin decidua* (*interna* or *reflexa*, Fig. 196 *de*, Fig. 199 *f*) is that part of the mucous lining of the womb which encloses the remaining surface of the sacrum, the smooth chorion (*chorion laeve*), in the shape of a special thin membrane. The origin of these three different *deciduas membranæ*, in regard to which some erroneous views (still retained in their names) formerly prevailed, is now quite clear. The external *decidua vera* is the specially modified and subsequently

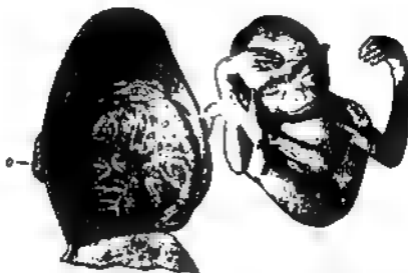


FIG. 197.—Right embryo of the Blushing-grass (*Syntherisma sanguinea*) of Schimper. (Enlarged natural size.) In the left the chorion-villi, of which only the dorsal half is given. The embryo has been taken out for the first time together, it is still connected by the umbilical cord with the corner of the chorion-placenta, which is attached to the inside of the womb. This embryo takes the development in the womb, and then is external in such a way.

brane"), and also the "*decidua capsularis*," hence it is perforated like a sieve. We find a *decidua* of this kind in most of the higher placentalis, but it is only in man and the anthropoid apes that it divides into three parts—the outer, inner, and placental *decidua*. The external or true *decidua* (Fig. 196 *de*, Fig. 199 *f*) is the part of the mucous lining of the womb that clothes the inner surface of the intestine; wherever it is not connected with the placenta. The placental or spongy *decidua* (*placentalis* or *serosa*, Fig. 196 *de*, Fig. 199 *d*) is really the placenta itself, or the maternal part of it (*placenta*

detachabilis superficial stratum of the original mucous lining of the womb. The placental *decidua capsularis* is that part of the preceding which is completely transformed by the ingrowth of the chorion-villi, and is used for constructing the placenta. The inner *decidua reflexa* is formed by the rise of a circular fold of the mucous lining (at the border of the *decidua vera* and *serosa*), which grows over the foetus (like the amnion) to the

The peculiar anatomical features the structure the human foetal membrane is found in just the same way in the higher

RETAL MEMBRANES AND CIRCULATION

apes. Until recently it was thought that the human embryo was distinguished by its peculiar construction of a solid allantois and a special ventral pedicle, and that the umbilical cord developed from this in a different way than in the other mammals. The opponents of the urweltmann "apothecary" laid great stress on this, and thought they had at last discovered an important indication that separated man from all the other placental. But the

described the allantois has no blood-vessels at any moment of its existence. But the other two vesicles, the yolk-sac and the allantois, are equipped with large blood-vessels, and these affect the nourishment of the embryonic body. We may take the opportunity to make a few general observations on the first circulation in the embryo and its central organ, the heart. The first blood-vessels, the heart, and the first blood itself, are formed from the

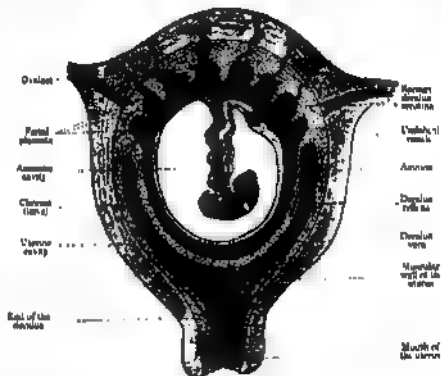


FIG. 16.—Frontal section of the pregnant human womb. Of course in the middle of the amniotic cavity, by the ventral pedicle of allantois (above).

remarkable discoveries published by the distinguished zoologist Schenck in 1880 proved that man shares these peculiarities of placentation with the anthropoid apes, though they are not found in the other apes. Thus the very features which were advanced by our critics as a *deposuit* became a most important piece of evidence in favour of our plithocoid origin.

Of the three vesicular appendages of the amniotic embryo which we have now

just-fine layer. Hence it was called by earlier embryologists the "vascular layer." In a sense the term is quite correct. But it must not be understood as if all the blood-vessels in the body came from this layer, or as if the whole of this layer were taken up only with the formation of blood-vessels. Neither of these suppositions is true. Blood-vessels may be formed independently in other parts, especially in the vascular products of the skin-fibre layer.

are called *amphibio-mesodermic* or *villous arteries*. They represent the first beginning of a fetal circulation. Thus, the first blood-vessels pass over the embryonic body and reach as far as the edge of the germinal area. At first they are united to the dark or "vascular" area. But they.

of the embryonic vesicle. In the end, the whole of the yolk-sac is covered with a vascular net-work. These vessels, other than the

the yolk-sac and convey it to the embryonic body. This is done by the veins, which pass first from the germinal area, and afterwards from the yolk-sac, to the farther end of the heart. They are called *villous*, or, frequently, *amphibio-mesodermic*, veins.

These vessels naturally atrophy with the degeneration of the villous vesicle, and the villous circulation is replaced by a second, that of the allantois. Large blood-vessels are developed in the wall of the urinary sac or the allantois, as before, from the gut-tube layer. These vessels grow larger and larger, and are very closely connected with the vessels that develop in the body of the embryo itself. Thus, the secondary, allantoic circulation gradually takes the place of the original villous circulation. When the allantois has attached itself to the inner wall of the chorion and has entered into the placenta, its blood-vessels alone effect the nourishment of the embryo. They are called *umbilical vessels*, and are originally double—a pair of umbilical arteries and a pair of umbilical veins. The two umbilical veins (Fig. 183 a), which convey blood from the placenta to the heart, open at first into the united villous vein. The latter then disappears, and the right umbilical vein goes with them, so that henceforth a single large vein, the left umbilical vein, conducts all the blood from the placenta to the heart of the embryo. The two arteries of the allantois, or the umbilical arteries (Figs. 183 a, 184 a), are merely the ultimate terminations of the primitive aorta, which are strongly developed afterwards. The villous circulation is retained until the nine months of embryonic life are over, and the human embryo enters into the world as an independent individual. The umbilical cord (Fig. 196 a), in which these large blood-vessels pass from the embryo to the placenta, comes away, together with the latter, in the after-birth, and

with the use of the large bagies an entirely new form of circulation, which is confined to the body of the infant.

There is a great phylogenetic significance in the perfect agreement which we find between man and the anthropoid apes in these important features of . . . bryonic circulation, and the special construction of the placenta and the villous cord. We must later from it a close blood-relationship of man and the anthropomorphic apes—a common descent of these from one and the same extinct



FIG. 183. 12-day-old embryo of the dog, from the ventral side, magnified about 100 times. It shows what the forelimb in the ape and the first pair of allantoic rudiments in the foetal body of the dog of which are the ordinary villous. The large vessel, which carries the blood, is the umbilical vein.

the pair of umbilical arteries are given off from

group of lower apes. Huxley's "phylogenetic-principle" applies to these ontogenetic features as much as to any other morphological relations: "The differences in construction of any part of the body are less between man and the anthropoid apes than between the latter and the lower apes."

This important Huxleyan law, the chief consequence of which is "the descent of man from the ape," has lately been confirmed in an interesting and unexpected way from the side of the experimental

physiology of the blood. The experiments of Hans Friedenthal at Berlin have shown that human blood, mixed with the blood of lower apes, has a pronounced

As we have seen, that the blood is only possible without injury in the case of two closely related animals or



FIG. 105.—LAP OF WHITE-THROATED GIBBON (*Haplorhina leucorhina*), seen through stained (From Becken)

effect on the latter, the serum of the one destroys the blood-cells of the other. But this does not happen when human blood is mixed with that of the anthropoid ape.

In the same family, we have another proof of the close blood-relationship, in the fact that of the world, of man and the anthropoid ape.

The existing anthropoid apes are only a small remnant of a large family of eastern apes (or *Catantropes*), from which man was evolved about the end of the Tertiary period. They fall into two geo-

graphical species of it in the East Indies. I made observations of four of them during my voyage in the East Indies (1890), and had a specimen of the ash-gray gibbon (*Hylobates leucurus*) living



FIG. 109.—YOUNG ORANGUTAN (*Pongo pygmaeus*), adelp.

graphical groups—the Asiatic and the African anthropoids. In each group we can distinguish two genera. The oldest of these four genera is the gibbon (*Hylobates*, FIG. 109); these are from

for several months in the garden of my house in Java. I have described the interesting habits of this ape (regarded by the Malays as the wild descendant of men who had lost their way) in my *Malayische*

Rhesus (chap. xi). Psychologically, he showed a good deal of resemblance to the children of my Malay hosts, with whom I played and formed a very close friendship.

The second, larger and stronger, genus of Asiatic anthropoid ape is the orang (*Pongo*), he is now found only in the islands of Borneo and Sumatra. Schreber,

like our ancient cheek-pads in the elderly male; these are wanting in the other group, the ordinary orang-outang (*Pongo*).

Several species have lately been distinguished in the two genera of the black African anthropoid apes (chimpanzee and gorilla). In the genus *Anthropithecus* (or *Anthropopithecus*, formerly) *Thyridorhina*,



FIG. 206.—WILD ORANG (*Pongo ssp.*) (From H. Fick and L. L. L. L.)

who has published a very thorough study of the *Development and Criminal Selection of the Anthropoid Apes* (1898), distinguishes ten races of the orang, which may, however, also be regarded as "local varieties or species." They fall into two sub-genera or genera, one group, *Pongopongo* (orang-benlang, Fig. 206), is distinguished for the strength of its limbs, and the formation of very pos-

sible bald-headed chimpanzee, *A. calvus* (Fig. 207), and the gorilla-like *A. maynii* differ very strikingly from the ordinary *Anthropithecus* *negro* (Fig. 207), not only in the size and proportion of many parts of the body, but also in the peculiar shape of the head, especially the ears and lips, and in the hair and colour. The controversy that still continues as to whether these different forms of



FIG. 164. — The bald-headed shrewmole (*Amelospiza calva*). From a series of sections described by Frank Peckham in 1897 as *Thalassidroma calva*, differs considerably from the ordinary *A. naga* (Fig. 167) in the structure of the head, the coloring, and the absence of hair on parts.

chimpanzees and orang are "merely local varieties" or "true species" as an idle one, as in all such disputes of elevation, there is an utter absence of clear ideas as to what a species really is.

Of the largest and most famous of all the anthropoid apes, the gorilla, Penchen has lately discovered a giant-form in the interior of the Cameroons, which seems to differ from the ordinary species (*Gorilla*

in that of man, but it is substantially the same. "The same sea bones, arranged in the same way, form our internal skeleton; the same 300 muscles effect our movements, the same hair covers our skin, the same groups of ganglionic cells compose the trigonitic mechanism of our brain; the same four-chambered heart is the central pump of our circulation." The really existing differences in the



FIG. 24.—Female *Gorilla* (*Gorilla gorilla*) (From Huxley)

gibba Fig. 24), not only by its unusual size and strength, but also by a special formation of the skull. This giant gorilla (*Gorilla gigan*, Fig. 25) is its feet eight inches long; the span of its great arms is about nine feet; its powerful chest is twice as broad as that of a strong man.

The whole structure of this huge anthropoid ape is not much very similar

shape and size of the various parts are explained by differences in their growth, due to adaptation to different habits of life and unusual use of the various organs. This of itself proves morphologically the descent of man from the ape. We will return to the point in the twenty-third chapter. But I wanted to point already to this important solution of "the question of questions," because that agreement

FOETAL MEMBRANES AND CIRCULATION

in the formation of the embryonic membranes and in fetal circulation which I have described affords a particularly weighty proof of it. It is the most instructive as even ontogenetic structures

very in certain circumstances have a high phylogenetic value. In conjunction with the other facts, it affords a striking confirmation of our biogenetic law.



Fig. 101.—*Gorilla gorilla*. (From Silliman.)



For me—My great-grandfather (Charles Henry) from Toronto, to the founder of the University. Killed by

THE EVOLUTION OF MAN

A POPULAR SCIENTIFIC STUDY

ERNST HAECKEL

VOL. II.

HUMAN ETHE-HISTORY, OR PHYLOGENY

WITH JOSEPH MCCABE

WATTS & Co.,

17, JOHNSON'S COURT, FLEET STREET, LONDON, E.C.

1923

*Printed (or made) in Great Britain
by Watts & Co., Johnson's Court, Fleet Street,
London, E C 4*

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CHAPTER XVI.

STRUCTURE OF THE LANCELET AND THE SEA-SQUIRT

In turning from the embryology to the phylogeny of man—from the development of the individual to that of the species—but the direct causal

link that exists between these two

evolution. This important finds its simplest expression in "the fundamental law of organic development," the content and purport of which we have fully considered in the first chapter. According to this biogenetic law, ontogeny is a brief and condensed recapitulation of phylogeny. If this comprehensive reproduction were complete in all cases, it would be very easy to construct the whole story of evolution on an embryonic basis. When we wanted to know the ancestors of any higher organism, and, therefore, of man—to know from what forms the race as a whole has been evolved—we should merely have to follow the series of forms in the development of the individual from the ovum; we could then regard each of the successive forms as the representative of an extinct ancestral form. However, the direct application of ontogenetic facts to phylogenetic ideas is possible, without limitations, only in a very small section of the animal kingdom. There are, it is true, still a number of lower invertebrates (for instance, some of the Zoophyta and Vermata) in which we are justified in recognizing at once each embryonic form as the historical reproduction, or silhouette, as it were, of an extinct ancestor. But in the great majority of the animals, and in the case of man, this is impossible, because the embryonic forms themselves have been modified through the change of the conditions of existence, and have lost their original character to some extent. During the immeasurable course of organic history, the many millions of years during which life was developing on our planet, secun-

dary changes of the embryonic forms have taken place in most animals. The young of animals (not only at the larva, but also the embryos enclosed in the womb) may be modified

from the conditions of life; even species are altered during the embryonic development. Moreover, it is an advantage for all higher organisms (and the advantage is greater the more advanced they are) to conceal and simplify the original course of development, and thus to obliterate the traces of their ancestors. The higher the individual organism is in the animal kingdom, the less completely does it reproduce in its embryonic development the series of its ancestors, for reasons that are as yet only partly known to us. The fact is easily proved by comparing the different developments of higher and lower animals in any single stem.

In order to appreciate this important feature, we have distributed the embryological phenomena in two groups, paleogenetic and ontogenetic. Under paleogenetics we count those facts of embryology that we can directly regard as a faithful synopsis of the corresponding stem-history. By ontogenetics we understand those embryonic processes which we cannot directly correlate with corresponding evolutionary processes, but must regard as modifications or falsifications of them. With this careful discrimination between paleogenetic and ontogenetic phenomena, our biogenetic law assumes the following more precise shape: rapid and brief development of the individual (ontogeny) is a condensed synopsis of the long and slow history of the stem (paleogeny): this synopsis is the more faithful and complete in proportion as the original features have been preserved by heredity, and modifications have not been introduced by adaptation.

In order to distinguish correctly between paleogeographic and neogeographic phenomena in embryology, and deduce sound conclusions in connection with embryology, we must especially make a comparative study of the former. In doing this it is best to begin, the methods that have long been used by geologists for the purpose of establishing the succession of the sedimentary rocks on the coast of the north. This will mean, a brief survey of the glacial period, which means, in connection of different basins of coasts, there are, first, the volcanic rocks which were formed directly by the cooling of the surface of the molten mass of the earth. Secondly, there are the sedimentary rocks, that have been made out of the former in the course of a year, and have been laid in successive strata at the bottom of the sea. Much of these sedimentary rocks are of first a soft layer of sand, but in the course of thousands of years a cementation into a solid, hard mass of sand (sandstone, limestone, marl, etc.), and at the same time permanently preserved of the solid and impermeable bodies that had obtained to fall into the soft mud. Among these bodies, which were either landward or both character—a representation of their forms in the soil alone, we have especially the more solid parts of the animals and plants that lived and died during the duration of the glacial period.

From each of the sedimentary rocks has a characteristic fossils, the remains of the animals and plants that lived during that particular period of the earth's history. When we make a comparative study of these strata, we can survey the whole series of such periods. All geologists are now agreed that we can distinguish a definite historical succession in the rocks, and that the lower of these were deposited in very remote, and the uppermost in comparatively recent, times. However, there is no part of the earth where we find the series of strata in so strictly, or even approximately complete. The examination of strata and of corresponding historical periods generally given in geology is an ideal construction, arrived by putting together the various parts: fragments of the succession of strata that have been made in different parts of the earth's surface (cf. Chapter XVIII.).

We must act in this way in constructing the phylogeny of man. We must try to piece together a fairly complete picture of

the series of our ancestors from the earliest phylogenetic fragments that we find in the different groups of the animal kingdom. We should see that we are really in a position to form an approximate picture of the evolution of man and the mammals by a proper comparison of the embryology of very different animals—a picture that we could never have formed from the embryology of the mammals alone. As a result of the then-mentioned neogeographic processes—those of disturbed and curtailed heredity—a whole series of lower stages have dropped out in the embryonic development of man and the other mammals, especially from the earliest periods, or been obliterated by modification. But we find these lower stages in their original purity in the lower vertebrates and their immediate ancestors. Especially in the lower of all the vertebrates, the lampreys and amphioxys, we have the embryonic conditions completely preserved in the embryonic development. We also find important evidence in the fishes, which stand between the lower and higher vertebrates, and throw further light on the course of evolution in certain periods. Next to the fishes, come the amphibians, from the embryology of which we can also draw instructive conclusions. They represent the transition to the higher vertebrates, in which the middle and older stages of ancestral development have been either discarded or curtailed, but in which we find the more recent stages of the phylogenetic process well preserved in a summary. We are then in a position to form a fairly complete idea of the past development of man's ancestors, when the neogeographic events by putting together and summarizing the embryological development of the various groups of vertebrates. And as we go below the lower vertebrates and compare their embryology with that of the more recent mammals we can follow the morphological line of our animal ancestors back farther down to the very ancient groups of animals.

In carrying the embryonic paths of the phylogenetic labyrinth, clinging to the broadest thread of the biogenetic law and guided all the light of comparative anatomy, we will find, in accordance with the methods we have adopted, discovered and arranged these fragments from the ramified embryonic development of very different animals from which the embryology of man can be composed. I could call attention particularly to the fact that

employ this method with the same confidence and right as the geologist. No geologist has ever had clearer proof that the vast rocks that compose our Carboniferous or Jurassic or Cretaceous strata were really deposited in water. Yet no one doubts the fact. Further, no geologist has ever learned by direct observation

these various sedimentary formations deposited in a certain order, yet all are agreed as to this order. This

cannot be rationally understood

until Three hypotheses are made and independent

geological

the same value, for the same reason. In formulating them we are acting on the same inductive and deductive methods, and with almost equal confidence, as the geologist. We hold them to be correct, and claim the status of "biological theories" for them, because we cannot understand the nature and origin of man and the other organisms without them,

knowledge of biological hypothesis

independent century are now universally limited, so our phylogenetic hypotheses, which are still regarded as *hypotheses* in certain quarters, will sooner or later be generally received. It is true that, as all soon appear, our task is not so simple as that of the geologist. It is just as much more difficult and complex as with organization is more elaborate than the structure of the rocks.

When we approach this task, we find a surmounting of the utmost importance as to comparative anatomy and embryology in our lower animal kingdom. One of these animals is the lancelet (*Amphioxus*), the other the sea-squirt (*Ascidia*). Both are at the border between the two chief divisions of the animal kingdom—

invertebrates and

The slowly mentioned the Amphioxus

(scarcely, lampreys, fishes, dipnoans, amphibians, reptiles, birds, and mammals). Following the example of Lamarck, it is usual to put all the other animals together under the head of invertebrates. But, as I have often mentioned already, the group

is composed of a number of very different stems. Of these we have no interest just now in the phlebotomids, molluscs, and arthropods, as they are independent branches of the animal-tree, and have nothing to do with the vertebrates. On the other hand, we are greatly concerned with a very interesting group that has only recently been carefully studied, and that has

the vertebrates.

the stem of the Vertebrates. One of this group, the sea-squirt, very closely approaches the lowest vertebrate, the Amphioxus, in its essential internal structure. I can only say that until one had any idea of the close relationship

made, it was a very fortunate accident that the embryology of these related forms was discovered just at the time when the question of the descent of the vertebrates from the invertebrates came to the front. In order to understand it properly, we must first consider these remarkable animals in their fully-developed forms and compare their anatomy.

It lives on the flat, sandy parts of the Mediterranean coast, partly buried in the sand, and is apparently found in a number of seas. It has been found in the North Sea (on the British and Scandinavian coasts and in Heligoland) and at various places on the Mediterranean (for instance, at Nice, Naples, and Messina). It is also found on the coast of Brazil and on the most distant parts of the Pacific Ocean (the coast of Peru, Mexico, China, Australia, etc.). Recently eight to ten species of the amphioxus have been determined, distributed in two or three genera.

Johnston Muller classed the lancelet with the fishes, although he pointed out that the difference between this simple vertebrate and the lowest fishes are much greater than between the fishes and the amphioxus. But this was far from expressing the real significance of the difference.

... suddenly lay down the following principle: The Amphioxus differs more from the fishes than the fishes do from

* See the complete monograph by Arthur Willey, *Amphioxus and the Ancestry of the Vertebrates*.

(*ovum*). Of these the only living representatives are the Amphioxus and Petromyzonidae, though there must have been a number of different species at an early period of the earth's history.

Compared to the Arthropoda is the most primitive of the vertebrates, which comprises all the other members of the class, from the fish up to man. All these vertebrates have a head quite distinct from the trunk, with a skull (*cranium*), and eyes; all have a circulatory heart, fully-developed kidneys, etc. Hence they are called the Crustacea. These Crustacea are, however, without a skull or other special parts. An interesting source from embryology, even then, that every other member, points to the fact that even at the first development through the embryonic stage which we call the *larva*, as the lower stage the animal has certain features not found in the Crustacea (Figs. 49-51). And even after the formation of the primitive vertebrate has begun, the important features of the animal will not for a long time be the simple form of a hatched embryo or a small crustacean larva or crustacean. When we compare this embryonic condition, the undeveloped stage, with the developed lancelet, we may say that the lancelet is, in a certain sense, a permanent paedulogical, or a permanent embryonic form of the Arthropoda. It does not show a low grade of development which the lower forms possess.

The fully-developed lancelet (Fig. 202) is about two inches long, is colorless or of a light red tint, and has the shape of a slender lance without tail. The body is pointed at both ends, but much compressed at the sides. There is no trace of limbs. The outer skin is very thin and delicate, colored transparent, and composed of two different layers, a single external covering of cells, the epidermis, and a thin underlying cuticle-layer. Along the middle line of the body runs a narrow fold-like ridge which extends behind into an oval tail-like, and a continuous, below in a short caudal fin. The fold-like ridge is supported by a number of square slender laminae.

In the middle of the body we find a thin string of cartilage, which gives the whole length of the body from head to tail, and is perforated at both ends (Fig. 202 c). This strongly cylindrical and somewhat compressed bar is called the notochord or the chord dorsalis. At the anterior end it is the only trace of a vertebral column. The chorda develops no further, but retains

its original simplicity throughout life. It is enclosed by a firm membrane, the chorda-sheath or notochord. The end branches of the cord of the dependent laminae are lost soon in the transparent tissue of the Amphioxus (Fig. 211). The notochord forms a cylindrical tube immediately over the chorda, and the central nervous system, the medullary tube, is contained in it. This superior parallel organ also remains in its simplest stage throughout life as a cylindrical tube, remaining with almost equal thickness at either end, and forming a narrow canal in its thick wall. However, the fore end is a little rounded, and contains a small, almost imperceptible bulging swelling of the neural. This swelling is regarded as the beginning of a rudimentary brain. At the foremost end of it there is a small thick pigment-spot, a rudimentary eye, and a narrow slit, leads to a superficial cutaneous eye. In the vicinity of this eye spot we find at the left side a small dilated depression, the single auditory organ. There is no organ of hearing. This anterior development of the higher vertebrates is probably, in the main, not an original feature, but a result of degeneration.

Underneath the dorsal rod or chorda runs a very simple accessory canal, a tube that opens on the ventral side of the animal by a small hole and does not branch. The ventral canal is surrounded by a ring of cartilage, on which there are resting the thirty cartilaginous chords (Fig. 202 c). The accessory canal divides into portions of about equal weight by a constriction in the middle. The two portions, or branches, serve for respiration, the hind portion, or caudal, for degeneration. The front of the two accessory portions is called the front of the two parts of the body, the head and the trunk. The head-like or head-like part forms a broad gill-cavity, the gill-cavity of which is perforated by openings of gill-cells (Fig. 202 d). The two parts of the gill-cavity between the chords are strengthened with four parallel rods, and these are connected in pairs by cross-rods. The water that enters the mouth of the Amphioxus passes through these gills into the large surrounding branched cavity or stream, and then flows out behind through a hole in it, the respiratory pore (Figs. 202 e, f, g). Below, on the ventral side of the gill-cavity, there is in the middle

straight vessel that runs along the dorsal line of the gut above, between it and the chorda, and contains arterial blood, is clearly identical with the aorta or principal artery of the other vertebrates; and on the other side it may be compared to the dorsal vessel in the worms.

The coloma or body-cavity has some very important and distinctive features in the Amphioxus. The embryology of it is most instructive in connection with the later-history of the body-cavity in man and the other vertebrates. As we have already seen (Chapter X), in these the two colomaspouches are divided at an early stage by transverse constrictions

(cf. A). As a matter of fact, this *abdomen* (commonly called the peribranchial cavity) is a secondary structure formed by the development of a couple of lateral

folds or gill-coverings (*M*, *U*). The body-cavity (*Lb*) is very narrow and entirely closed, lined with epithelium. The peribranchial cavity (*A*) is full of water, and its walls are lined with the skin-muscle layer, it opens outwards in the rear through the respiratory pore (Fig. 200 c).

On the later surface of these mantle-folds (*M*, *U*), on the ventral half of the wide mantle cavity (atrium), we find the sex-organs of the Amphioxus. At each

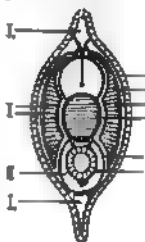
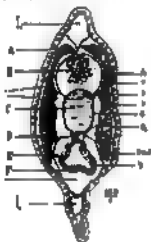


FIG. 199. Longitudinal section of a young *Amphioxus*, showing the metamorphosis through the stages of the larva and the adult. In the upper part of the diagram, the mouth, the pharynx, the branchial gut, the chorda, the dorsal vessel, the epibranchial plate, the pharynx, the gill-bar, the heart, the intestine, the kidney, the liver, the lung, the mantle fold, the notochord, the operculum, the peribranchial cavity, the quadrant, the respiratory pore, the sperm-cells, the testis, the uterus, the ventral vessel, the wrist, the xiphoid process, the yolk, the zygote.

into a double row of primitive segments (Fig. 124), and each of these subdivides, by a frontal or lateral constriction, into an upper (dorsal) and lower (ventral) pouch.

These important structures are seen clearly in the trunk of the amphioxus (the latter third, Figs. 202-205), but in otherwise in the head, the foremost third (Fig. 216). Here we find a number of complicated structures that cannot be understood until we have studied them on the embryological side in the next chapter (cf. Fig. 87). The branchial part then runs in a continuous cavity filled with water, which was wrongly thought formerly to be the body-cavity (Fig.

side of the branchial gut there are between twenty and thirty roundish four-cornered sacs, which can clearly be seen from without with the naked eye, as they show through the thin transparent body-wall. These sacs are the sexual glands; they are the same size and shape in both sexes, only differing in contents. In the female they contain a quantity of simple ova (Fig. 209 c), in the male a number of much smaller cells that change into mobile ciliated cells (sperm-cells). Both sacs lie on the inner wall of the atrium, and have no special outlets. When the sacs of the female and the sperm of the male are ripe, they fall into the atrium through the gill-clefts into the f

gut, and are ejected through the mouth.

Above the sexual glands, at the dorsal angle of the atrium, we find the kidneys. These important excretory organs could not be found in the *Amphioxus* for a long

other vertebrates (Fig. 218 *B*). Their internal aperture (Fig. 217 *B*) opens into the body-cavity; their outer aperture into the atrium (*C*). The prerenal canals lie in the middle of the line of the head, outwards

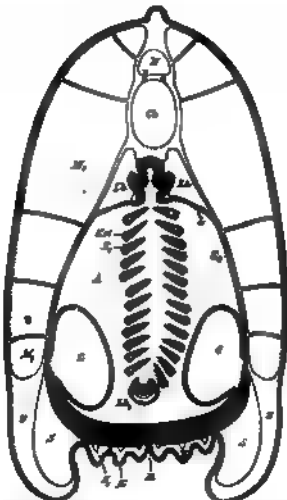


FIG. 216.—Transverse section of the lancelet, in the fore half. (From *Smith*.) The white covering is the simple epithelium of the epidermis (*B*). Under this is the thin nervous, the subdermal tissue of which is indicated. A much coarser nervous substance between the muscles (*M*) and to the chordal sheath. *H* muscle. *L* body cavity. *A* atrium. *E* upper wall of same. *D* outer wall. *H* water wall. *L* water wall. *M* muscle. *N* notochord. *O* neural tube. *P* prerenal canals. *Q* prerenal canals. *R* prerenal canals. *S* prerenal canals. *T* prerenal canals. *U* prerenal canals. *V* prerenal canals. *W* prerenal canals. *X* prerenal canals. *Y* prerenal canals. *Z* prerenal canals.

tissue, on account of their remote position and their smallness; they were discovered in 1890 by Theodor Boveri (Fig. 217 *A*). They are short segmental canals, corresponding to the primitive kidneys of the

most the uppermost section of the gill-slit, and have important relations to the branchial vessels (*H*). For this reason, and in their whole arrangement, the primitive kidneys of the *Amphioxus*

show clearly that they are equivalent to the preoral canals of the Crustacea (Fig. 218 B). The preoral duct of the lancelet (Fig. 218 C) corresponds to the branchial cavity or atrium of the former (Fig. 217 C).

If we sum up the results of our anatomic study of the Amphioxus, we

both animals in the same division of the animal kingdom. Nevertheless, this classification is indisputably just. Man is only a more advanced stage of the vertebral type that we find unmistakably in the Amphioxus in his characteristic features. We need only recall the structure of the ideal Primitive Vertebrate

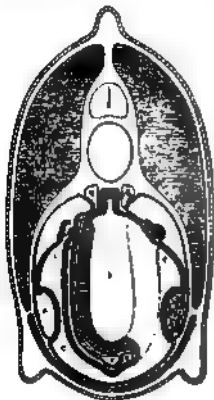


Fig. 217.—Transverse section through the middle of the Amphioxus. (From Huxley.) On the left a gill-vent has been struck, and on the right the pharynx, consequently on the left we see the whole of a preoral canal (A), on the right only the section of a broader A genital chamber (ventral) section of the pharynx, B branchial sacs, C ventral cavity, D subventral vessel, E snout (the left branch surrounded by a branchial vessel with the subventral vessel, F small vessel).

compare them with the familiar organization of man, we shall find an immense distance between the two. As a fact, the highest summit of the vertebrate organization which man represents is in every respect so far above the lowest stage, at which the lancelet remains, that one would at first scarcely believe it possible to class

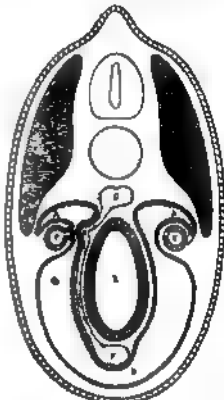
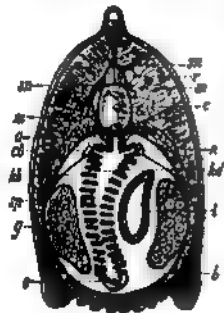


Fig. 218.—Transverse section through the middle of the Amphioxus. (From Huxley.) On the left a gill-vent has been struck, and on the right the pharynx, consequently on the left we see the whole of a preoral canal (A), on the right only the section of a broader A genital chamber (ventral) section of the pharynx, B branchial sacs, C ventral cavity, D subventral vessel, E snout (the left branch surrounded by a branchial vessel with the subventral vessel, F small vessel).

given in a former chapter, and compare it with the lower stages of human embryonic development, to convince ourselves of our close relationship to the lancelet. (Cf. Chapter XI.)

It is true that the Amphioxus is far below all other living vertebrates. It is true that it has no separate head, no developed brain or skull, the characteristic features of the other vertebrates.

It is (probably as a result of degeneration) without the accessory organ and the ventral heart that all the others have; and it has no fully-formed kidneys. Every single organ in it is simpler and less advanced than in any of the others. Yet the characteristic connection and arrangement of all the organs is just the same as in the other vertebrates. All these, moreover, pass, during their ontogenetic development, through a stage in which their whole organisation is no higher than that of the Amphioxus, but is substantially identical with it.



denticle, b gill-cover, c pharynx, d notochord, e pharynx, f gill-cover, g gill-cover, h gill-cover, i gill-cover, j gill-cover, k gill-cover, l gill-cover, m gill-cover, n gill-cover, o gill-cover, p gill-cover, q gill-cover, r gill-cover, s gill-cover, t gill-cover, u gill-cover, v gill-cover, w gill-cover, x gill-cover, y gill-cover, z gill-cover.

In order to see this quite clearly, it is particularly useful to compare the Amphioxus with the youthful form of those vertebrates that are classified next to it. This is the case of the Cyclostoma. There are to-day only a few species of

be distributed in two groups. One group comprises the lampreys or Myxosomata. The other group are the Petromyzontes, which are a

familiar fishery in their marine form. These Cyclostoma are usually classified with the fishes. But they are far below the true fishes, and form a very interesting connecting-group between them and the lancelet. One can see how closely they approach the latter by comparing a young lamprey with the Amphioxus. The chorda is of the same simple character in both, also the notochord tube, that lies above the chorda, and the

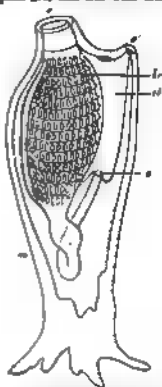
cardinal blood. However, in the lamprey the spinal cord starts in front into a simple pear-shaped cerebral vesicle, and at each side of it there are a very simple eye and a rudimentary auditory vesicle. The nose is a single pit, as in the Amphioxus. The two sections of the gut are also just the same and very rudimentary in the lamprey. On the other hand, we see a great advance in the structure of the heart, which is found underneath the gills in the shape of a contracted muscular tube, and is divided into an auricle and a ventricle. Later in the lamprey's advance still further, and gives a still, the ventral section, a series of independent gill-pouches on. This makes all the more in the striking resemblance of its immature form in the developed and actually mature Amphioxus.

While the Amphioxus is thus connected through the Cyclostoma with the fishes, and so with the series of the higher vertebrates. It is, on the other hand, very closely related to a large invertebrate marine animal, from which it seems to be directly sprung at first glance. This remarkable animal is the sea-squirt or Ascidia, which was formerly thought to be closely related to the molluscs, and so placed in the molluscs. But since the remarkable embryology of these animals was discovered in 1860, there can be no question that they have nothing to do with the molluscs. To the great astonishment of zoologists, they were found, in their whole individual development, to be closely related to the vertebrates. When fully developed the Ascidia are lampreys, that would not, at first sight, be taken for animals at all. The oval body, frequently studded with knobs or tubercles and bumps, in which we can discover no special external organs, is

or the floor of the sea. Many species look like potatoes, others like melon-cucis, others like pears. Many of the Ascidia form transparent crusts or

deposits on stones and waving plants. Some of the larger species are often like oysters. Fishermen, who know them very well, think they are not animals, but plants. They are sold in the fish markets of many of the Italian coast-towns with other lower marine animals under the name of "sea-fruits" (*frutti di mare*). There is nothing about them to show that they are animals. When they are taken out of the water with the net the most one can perceive is a slight contraction of the body that causes water to spout out in two places. The bulbs of the *Ascidia* are very small, at the most a few inches long. A few species are a foot or more in length. There are many species of them, and they are found in every sea. As in the case of the *Asperula*, we have no fossilised remains of this class, because they have no hard and fossilisable parts. However, they must be of great antiquity, and must go back to the pre-cambrian epoch. The name of "Tunicata" is given to the whole class to which the *Ascidia* belong, because the body is enclosed in a thick

outgrowth by the large grated branchial sac (b). This is so like the gill-crate of the *Amphioxus* in its whole arrangement that the resemblance was pointed out by the English naturalist Goodair, years ago, before anything was known of the relationship of the two animals. As a fact, even in the *Ascidia* the mouth (c) opens first into this wide branchial



in a number
marked as

typical substance
shape of the plant
the wood. The

that have a root cellulosic or woody coat. Sometimes the cellulosic substance is brightly coloured, in other times subcoloured. Not infrequently it is set with needles or hairs,

The sea-squirt (Ascidia) (left view). The dorsal side is turned to the right and the ventral side to the left. The mouth (c) opens into the branchial sac (b). The branchial sac is formed by a number of slits, and is the ventral part. The respiratory pore (d) opens into the branchial sac from which water is expelled with the respiratory water (b). The branchial sac is closed (b), in the *Ascidia*.)

1890-1891, p. 100. (The Ascidia is a member of the class Tunicata.)

The hind end, which corresponds to the tail of the *Amphioxus*, is usually attached, often by means of regular roots. The dorsal and ventral sides differ a good deal internally, but frequently cannot be distinguished externally. If we open the thick tunic or mantle in order to examine the internal organisation, we first find a spacious cavity filled with water—the mantle-cavity or respiratory cavity (Fig. 220 c). It is also called the branchial cavity and the cloaca, because it receives the excremental and sexual products as well as the respiratory water. The greater part of the respiratory cavity is

the respiratory water passes through the lattice-work of the branchial sac into the branchial cavity, and is ejected from this by the respiratory pore (d). Along the ventral side of the branchial sac runs a ciliated groove—the laryngeal groove which we have previously found at the same spot in the *Amphioxus*. The food of the *Ascidia* also

consists of tiny organisms, infusoria, diatoms, parts of decomposed marine plants and animals, etc. These pass with the water into the gill-craze and the digestive part of the gut at the end of it, at first into an enlargement of it that represents the stomach. The adjoining small intestine usually forms a loop, bends forward, and opens by an anus (Fig. 220 e), not directly outward, but first into the mantle cavity; from this the secretions are ejected by a common outlet (d) together with the waste-



Fig. 219.—Organization of an Ascidia (see p. 189).
Fig. 220.—Organization of an Ascidia (see p. 189).

water through the openings of the branchial pores (b) (see p. 189). (From the University of Chicago.)

water and the sexual products. The outlet is sometimes called the branchial pore, and sometimes the cloaca or ejection-aperture. In many of the Ascidia a glandular mass opens into the gut, and this represents the liver. In some there is another gland besides the liver, and this is taken to represent the kidneys. The body-cavity proper, or coelom, which is filled with blood and contains the hepatic gut, is very narrow in the Ascidia, as in the Amphioxus, and is here

also usually compounded with the whole stream, or peribranchial cavity, full of water.

There is an Ascidia of

sexual structure. It is the more interesting that the young animal that emerges from the ovum has a chorda, and that there is a rudimentary medullary tube above it. The latter is wholly atrophied in the developed Ascidia, and looks like a small nerve-ganglion in front above the gill-craze. It corresponds to the upper "gullet-ganglion" or "peristaltic brain" in other tunicates. Special sense-organs, not either wanting altogether or are only found in a very rudimentary form, as simple optic spots and touch-corpuscles or uncinates that surround the mouth. The muscular system is very slightly and irregularly developed. Immediately under the pharynx, and closely connected with it, we find a thin muscle, as in the worm. On the other hand, the Ascidia has a muscular heart.

In this respect it seems to be more advanced than the Amphioxus. On the ventral side of the gut, some distance behind the gill-craze, there is a spindle-shaped heart. It retains permanently the simple tubular form that we find impermanently as the first structure of the heart in the vertebrates. This simple heart of the Ascidia has, however, a remarkable peculiarity. It contracts in alternate direction. In all other animals the beat of the heart is always in the same direction (generally from rear to front), it changes in the Ascidia in the same direction. The heart contracts first from the rear to the front, and then for a moment, and then begins to beat the

alternately an anterior and veins. This feature is found in the Tunicates alone.

Of the other chief organs we have still to mention the sexual glands, which lie right behind in the body-cavity. All the Ascidia are hermaphrodites. Each individual has a male and a female gland, and so is able to fertilize itself. The eggs (e) fall directly from the ovary (o) into the mantle-cavity. The male sperm is conducted

to the female (f) by a special duct (s). Fertilization is accomplished here, and in many of the Ascidia developed embryos are found. These are then

ected with the breathing-water through the cloaca (*q*), and so "born alive."

If we now glance at the entire structure of the simple *Ascidia* (especially *Phallusia*, *Cynthia*, etc.) and compare it with that of the *Amphioxus*, we shall find that the two have few points of contact. It is true that the fully-developed *Ascidia* resembles the *Amphioxus* in several important features of its internal structure, and especially in the peculiar character of the gill-plate and gut. But

in most other features of organization it is so far removed from it, and is so unlike it in external appearance, that the really close relationship of the two was not discovered until their embryology was studied. We will now compare the embryonic development of the two animals, and find to our great astonishment that the same embryonic form develops from the ovum of the *Amphioxus* as from that of the *Ascidia*—a typical chordate.

CHAPTER XVII.

EMBRYOLOGY OF THE LANCELET AND THE SEA-SQUIRT

so prominent that there was the greatest difficulty in the earlier stages of classification in determining the affinity of these two great groups. What scientists began to speak of the affinity of the various animal groups in more than a figurative—in a genealogical—sense, this question came at once to the front, and seemed to constitute one of the chief obstacles to the carrying-out of the evolutionary theory. Even earlier, when they had studied the relations of the chief groups, without any idea of real genealogical connection, they believed they had found here and there among the invertebrates points of contact with the vertebrates. . . . of the worms, especially, seemed to approach the vertebrates in structure, such as the marine arrow-worm (*Sagitta*). But on closer study the analogies proved untenable. When Darwin gave an impulse to the construction of a real stem-history of the animal kingdom by his reform of the theory of evolution, the solution of this problem was found to be particularly difficult. When I made the first attempt in my *General Morphology* (1866) to work out the theory and apply it to classification, I found no problem of phylogeny that gave me so much trouble

But just at this time the true link was discovered, and at a point where it was least expected. Towards the end of 1866 two works of the Russian zoologist, Kowalevsky, who had lived for some time at Naples, and studied the embryology of the lower animals, were issued in the publications of the St. Petersburg Academy. A fortunate accident had directed the attention of this able observer almost simultaneously to the embryology of the lowest vertebrates, the *Amphioxus*, and that of an invertebrate, the close affinity of which to the *Amphioxus* had been least suspected, the *Ascidia*. To the extreme astonishment of all zoologists who were interested in this important question, there turned out to be the closest resemblance in structure from the commencement of development between these two very different animals—the lowest vertebrate and the misshapen, sessile invertebrate. With this undeniable identity of ontogenesis, which can be demonstrated to an astounding extent, we had, in virtue of the biogenetic law, discovered the long-sought genealogical link, and definitely identified the invertebrate group that represents the nearest blood-relatives of the vertebrates.

The discovery was confirmed by other embryologists, and there can no longer be any doubt that of all the classes of vertebrates that of the Tunicates is most closely related to the Vertebrates, and of the Tunicates the nearest are the Ascidians. We must say that the vertebrates are descended from the Ascidians—not all but from the *reptiles*—but we can say that of all the vertebrates it is the Tunicates, and within this group, the Ascidians, that are the nearest blood-relatives of the vertebrate stem-form of the vertebrates. We must assume as the common ancestral group of both stems as springing from the common vertebrate stem, the *Protobranchia* or *Protobranchia* ("primitive branchiata").

In order to appreciate fully the common side here, and especially to secure the exact lines to which the generalization of the vertebrates, it is necessary to study thoroughly the embryology of both these groups, and especially the developmental stages of the Amphioxus step by step with that of the Ascidia. We begin with the embryology of the Amphioxus.

From the considerable observations of Kowalevsky at Naples and Huxley at Vienna, it follows, first, that the segmentation and gastrulation of the Amphioxus are of the simplest character. This takes place in the same way as we find them in many of the lower animals of definite unbranching nature, which we have already described as typical in vertebrates. The development of the Ascidia is of the more type. Branchiostoma specimens of the Ascidia, which are found in great quantities at Messina from April to May onwards, begin as a rule to eject their sexual products in the evening; if you catch them about the middle of a warm night and put them in a glass vessel with seawater, they immediately open through the mouth their rudimentary sexual products, in consequence of the disturbance. The males give out masses of sperm, and the females discharge one or two quantities that many of them stick to the filter about their mouths. Both kinds of cells pass first into the mantle cavity after the opening of the gonads, proceed through the gill-stalk into the branchial gut, and are discharged from this through the mouth.

The eggs are simply round cells. They are only one of an inch in diameter, and they are only half the size of the smallest

ova, and have no distinctive features. The clear protoplasm of the mature ovum is made up of the nucleus of dark granules of food-particles or chromatophores contained in it that it is difficult to follow the process of fertilization and the subsequent of the two nuclei during it (p. 51). The mature ova of the Ascidia, the egg-shaped ova, are similar to those of most other animals (cf. Fig. 20). Fertilization takes place when three dark stained cells of the sperm approach the ovum, and each penetrates into the yolk-nucleus of the cellular substance of the ovum with their long-pointed, the darker part of the cell, and enters the nucleus. Only one spermatozoon can thus do so, and the cell of one pair of the spermatozoa, by itself or one or two spermatozoa with the female nucleus, which contains the nucleus of the germinal vesicle from the germinal vesicle. This is formed the "zygote," or the nucleus of the "zygote" (cf. Fig. 21). The zygote undergoes rapid segmentation, dividing into two, four, eight, sixteen, thirty-two cells, and so on. In this way we get the spherical, mother-shaped body, which we call the morula.

The segmentation of the Ascidia is not entirely regular, as was supposed after the first observations of Kowalevsky (1885). It is not completely equal, but it is little unequal. As Huxley afterwards found (1895) the segmentation is only regular up to the morula-stage, the spherical body of which consists of thirty-two cells. From this stage onwards, the unequal segmentation, the more unequal regular cells are not regular in the cleavage. At the base or apical pole of the ovum a row of eight large cells develops with numerous for a long time unchanged while the other cells divide, owing to the formation of a series of horizontal rows, one an increasing number of rows of cells, each with more and more segmentation cells get more and more regularly displaced, while the segmentation-cells undergo in the center of the morula, in the end the former all lie on the surface of the latter, so that the latter contain the smaller Morula cells and form the wall of a cell around a single structure of cells (Fig. 22 A-C). This type is the Morula, the simple spherical form of cells of which all the tissues of the body proceed.

These important early embryonic processes take place so quickly in the Amphioxus that four or five hours after fertilization, or about midnight, the spherical blastula is completed. A pallid depression is then formed at the ventral pole of it, and in correspondence of this the hollow sphere divides on itself (Fig. 38 D). The pale basement deeper and deeper (Fig. 38 A, F); it has the appearance (for shading) is complete, and the lower or folded part of the blastula-wall lies on the inside of the outer wall. We then get a hollow hollow-sphere, the thin wall of which is made up of two layers of cells. (Fig. 38 E). From hemispherical the body soon becomes almost spherical more or less, and then and the internal cavity enlarging accordingly and the mouth growing narrow (Fig. 38 J). The form which the embryo assumes has then appeared in a form "cylindrical or globular, of the original shape, as then a large previously developed on the "hollow-sphere" or an "epithelium" (Fig. 38 J).

In all the other animals that form an embryonic stage a body such as nothing but a simple sphere and or somewhat, an internal cavity is the primitive gut (pharynx or stomodaeum. Fig. 38 G, 38 F), and its aperture the primitive mouth (pharynx or stomodaeum, a). The wall is at once gut-wall and body-wall. It is composed of a simple cell-layer, the function primary peritoneal layer. The inner layer or the invaginated part of the blastoderm, which immediately covers the gut-cavity is the endoderm, the outer or typical blastoderm, form a kind of over the wall of the alimentary canal and so on, are epidermis, the coelom, peritoneum, etc. (Fig. 38 J, 38 K). The outer layers of cells or the outer epidermis part of the blastoderm, is the periderm, the outer or external periderm, a kind of skin, the outer skin (epidermis), and the nutrition system (a). The cells of the endoderm are much larger, denser, and more fatty than those of the ectoderm, which are thinner and less rich in fatty particles. Hence before and during invagination there is an increasing differentiation of the inner from the outer layer. The animal cells of the outer layer soon develop secondary nuclei; the typical cells of the inner layer do so much later. A thread-like process grows out of each cell, and often continues vibratory movements. By the vibration of these threads the gut-cavity of the Amphioxus

soon forms about in the sea, when it has played the thin swimming, like the gastrula of many other animals (Fig. 38 K). In many other lower animals, the cells have a very long hair-like hair cells, and an very small flagellum (cilia) with (in contrast with the ciliated cells, which have a number of short cilia or cilia).

In the further course of the rapid development the somewhat ball-gastrula becomes elongated, and begins to flatten on one side, parallel to the long axis. The flattened side is the subsequent dorsal side; the opposite or ventral side remains curved. The latter gutter, some shortly than the former, with the result that the primitive mouth is fixed to the dorsal side (Fig. 38 L). In the middle of the dorsal surface a shallow longitudinal groove or furrow is formed (Fig. 38 L), and the edges of the body rise up on each side of this groove in the shape of two parallel swellings. This groove is, of course, the dorsal furrow, and the swellings are the dorsal or secondary swellings, they form the first structures of the notochord nervous system, the medullary tube. The secondary swellings now rise higher, the groove between them becomes deeper and deeper. The edges of the parallel swellings curve towards each other and at last meet, and the medullary tube is formed (Fig. 38 M, N). Hence the formation of a medullary tube out of the outer skin takes place in the most dorsal portion of the two extending arms of the Amphioxus in just the same way as we have found in the embryo of fish and the higher animals when the dorsal notochord forms.

Investigation with the microtome of the medullary tube so have in the Amphioxus embryo the formation of the chorda, the notochord, and the epidermis growing from them (Fig. 38 N, O). These processes show the place with characteristic simplicity and clarity, so that they are very instructive to compare with the conditions on the one hand and with the higher vertebrates on the other. While the medullary groove is sinking in the middle line of the flat dorsal side of the sea-animal, and its parallel edges tend to form the notochord chorda, the single chorda is formed directly underneath them, and on each side of this a pair of longitudinal, fold down the dorsal wall of the primitive gut. These longitudinal folds of the notochord grow from the primitive mouth, or from the lower

and hinder edge. Here we see at an early stage a couple of large ectodermal cells, which are distinguished from all the others by their great size, round form, and thin-grained protoplasm; they are the two germinal plates, or polar cells of the macrogamete (Fig. 8) *pl*. They indicate the actual starting-point of the two embryos, which grow from this spot and enter germinal layers, grow thenceforward from the primitive gut, and provide the cellular material for the middle layer.

Immediately after their formation ectoderm-plates of the Amphioxus embryo are divided into several parts by longitudinal and transverse folds. Each of the symphysis is divided into an upper dorsal and a lower ventral section by a couple of lateral longitudinal folds (Fig. 8a). But these are again divided by several parallel transverse folds into a number of segments, the primitive segments arranged symmetrically called by the zoologists names as "primitive vertebrae". They have a different future above and below. The upper or dorsal segments, the epimerites, live there as they later on, and form with their cells the muscular plates of the trunk. The lower or ventral segments, the hypomeres, correspond to the lateral plates of the

Amphioxus-embryo, fuse together in the upper part owing to the disappearance of their lateral cells, and thus form the later body cavity (metapleura). In the lower part they remain separate, and afterwards form the segmental grooves.

In the middle between the two lateral folds of the primitive gut, a single central cavity develops.

At an early stage in the middle line of the dorsal wall. This is the dorsal chord (Fig. 8, *dc* *ab*). This axial rod, often of foundation of the later vertebral column in all the vertebrates, and is the only representative of it in the Amphioxus, originates from the ectoderm.

In consequence of these important folding-processes in the primitive gut, the simple ectodermal tube divides into four different sections:—I., ventral side, the permanent alimentary canal or permanent gut: II., above, at the dorsal side, the axial rod or chord, and III., the two rudimentary, which immediately sub-divide into two structures—IIIa., above, on the dorsal side, the epimerites, the double row of primitive or metapleural segments; and IIIb., below, on each side of the gut, the hypomeres,

the two lateral plates that give rise in the sea-squid, and the ectoderm which partly unite to form the body cavity. At the same time the second or auxiliary tube is formed above the chord, on the dorsal surface, by the closing of the paired auxiliary foldings. All these processes, which outline the typical structure of the vertebrate, take place with astonishing rapidity at the embryo of the Amphioxus; in the afternoon of the first day, or twenty-four hours after fertilization, the young Amphioxus, the typical

is to night visible.

The other occurrences on the second day of development in the Amphioxus of the

the alimentary tube is found as an entirely closed, after the closing of the primitive mouth, is only communicated with the environment (metapleura) with the auxiliary tube. The permanent mouth is a secondary formation, or the opposite end. Here, at the end of the second day, we find a pit-like depression in the outer skin, which grows round and into the closed gut. The anus is formed behind in the same way a few hours later (in the evening of the additional gastrulation). In man and the higher vertebrates, as we have seen, no pit in the outer skin, they then penetrate through, gradually becoming connected with the blood ends of the closed gut-tube. During the second day the Amphioxus-embryo undergoes few other changes. The number of primitive segments increases, and generally amounts to fourteen, never forty-eight to fifty hours after impregnation.

Almost simultaneously with the formation of the mouth the first gill-clefts break through in the fore section of the Amphioxus-embryo (generally forty hours after the commencement of development). It is independent, as the first external dorsal is completely closed up. The further development of the fore section takes place up slowly, and

The body becomes much longer, and is compressed at the sides. The head-end being transformed in a sort of triangle. Two rudimentary sense-organs are developed in it. Inside we find the first blood-vessels, an upper or dorsal vessel, corresponding to the aorta, between the gut and the dorsal cord, and a lower or ventral

corresponding to the vena cava, between the gut and the ventral cord, and a lower or ventral

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Now, the gills or respiratory organ also are formed at the forward of the alimentary canal. The whole of the anterior or respiratory section of the gut is converted into a gill-plate, which is pierced laterally by numbers of branchial-holes, as in the ascidia. This is done by the forepart of the gut-wall joining one side with the outer skin, and the formation of clefts

we have previous
five Vertebrate" (Figs 98-102). But the body afterwards undergoes various modifications, especially in the fore-part. These modifications do not concern us, as they depend on special adaptations, and do not affect the hereditary vertebrate type. When the free-swimming Amphiox-

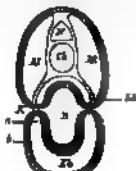


Fig. 98.



Fig. 99.

at the point of connection, piercing the wall and leading into the gut from without. At first there are very few of these branchial clefts; but there are soon a number of them—first in one, then in two.

The foremost gill-cleft is the oldest

In the formation of the gill-clefts, supported on a skeleton of stiff branchial rods; these were connected in pairs by transverse rods.

At an early stage of embryonic develop-

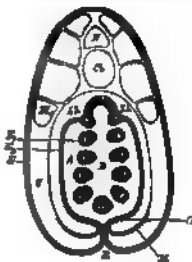


Fig. 100.

ment, the body is three months old, it abandons its pelagic habits and changes into the young animal that lives in the sand. In spite of its smallness (one-eighth of an inch), it has substantially the same organization as the adult. As regards the remaining organs of the Amphioxus, we need only mention that the gonads or sexual glands are developed very late, immediately out of the inner cell-layer of the

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body-cavity. Although we can find after-wards no continuation of the body-cavity (Fig. 216 E) in the lateral walls of the mantle-cavity, in the gill-covers or mantle-folds (Fig. 222 E), there is one present in the beginning (Fig. 224 Ld). The present cells are formed below, at the bottom of this continuation (Fig. 224 J). For the rest, the subsequent development into the adult Amphioxus of the larva we have followed is so simple that we need not go further into it here.

We may now turn to the embryology of the *Amplexus*, an animal that seems to stand in much lower and in no way more nearly organized, connection to the greater part of its life detached to the bottom of the sea like a *Caprellus* lamp. It was a fortunate accident that Dr. A. B. Sherrin first examined just those larger specimens of the *Amplexus* that show most clearly the relationship of the vertebrate to the invertebrate, and the basis of which further explains the value of the *Amplexus* in the history of development. This relationship is so clear in the adult stages that we have only to repeat what we have already said of the embryology of the *Amplexus*.

The eggs of the large *Amplexus* (Figs. 216, 217) are a simple round cell of egg to egg of an inch in diameter. In the thick four-grained cells we find a clear round germinal vesicle of about one of an inch in diameter and the nucleus a small elliptical spot of nucleolus beside the vesicle. The vesicle, the nucleus, the nucleus of the larva after fertilization, passes through all the same metamorphoses as the vesicle of the *Amplexus*. It undergoes total segmentation; it divides into two, four, eight, sixteen, thirty-two cells, and so on by continued total cleavage the vesicle, or embryonic vesicle, of cells, is formed. These groups divide in, and thus we get once more a phyllula vesicle (phyllophora); the wall of this is a single stratum of cells, the *blastoderm*. A new gastrula is thereby laid down, is formed from the blastoderm by invagination, in the same way as in the cephalopods.

Up to this there is no doubt ground in the embryology of the *Amplexus* for bringing them into close relationship with the Vertebrates; the same gastrula is formed in the same way in many other animals of different classes. But we now find an embryonic process that is peculiar to the Vertebrates, and that passes from

frugally the affinity of the *Amplexus* to the Vertebrates. From the epidermis of the gastrula a cellular tube is formed on the same side, and between the side and the primitive gut, a chorda. There are the organs that are otherwise only found in Vertebrates. The formation of these very important organs takes place in the *Amplexus* gastrula in precisely the same way as in that of the vertebrates. In the *Amplexus* (as in the other cases) the oral gastrula is first flattened on one side—the embryonic dorsal side. A process of invagination (the notochordal groove) is made in the middle line of the flat surface and two parallel longitudinal cuttings arise on either side from the dorsal face. These notochordal cuttings join together over the surface, and form a tube, in this case, again, the neural or notochordal tube is at first open to front, and surrounded with the primitive gut behind by the notochordal canal. Further, as the invagination of the two permanent appendages of the embryonic and only upper leaves, an independent and new formation. The permanent mouth does not develop from the primitive mouth of the gastrula, the primitive mouth closes up, and the later one is formed next to it by invagination from within, on the border end of the body, opposite to the aperture of the embryonic tube.

Through these appendages from the side tube there is now the water way in the vertebrates. A cellular process grows out at the posterior end of the larva, which, with the oral tube, will up within the mouth in the same way as in the case that the dorsal tube is formed and the oral is formed on the ventral side. In the tail is developed starting from the primitive gut, a cylinder of rings of cells, the foot end of which borders the body of the larva between the notochordal canal and the dorsal canal and is no other than the chorda dorsalis. This important organ had hitherto been found only in the Vertebrates, not a single trace of it being discoverable in the invertebrates. As from the chorda only remains of a single row of large cartilaginous cells. It is afterwards composed of several rows of cells. In the *Amplexus* larva, also, the chorda develops from the same middle part of the primitive gut where the two embryonic tubes detach themselves from it on both sides. The simple body-cavity is formed by the invagination of the cells.

When the *Amplexus* has attained

this stage of development it begins to move about in the ovules. This causes the membrane to burst. The larva emerges from it, and swims about on its own little tail.

These fry have been known for a long time. They were first observed by Darwin during his voyage round the world on H.M.S. They resemble tadpoles in outward appearance, and use their tails as oars, as the tadpoles do. However, this lively and highly-developed condition does not last long. At first there is a progressive development, the foremost part of the medullary tube enlarges into a brain, and inside this two single ventricles are developed, a dorsal auxiliary vessel and a ventral one. Then a heart is formed on the ventral side of the animal, or the lower wall of the gut, in the same simple form and at the same spot at which the heart is developed in fish, and

which, upon development

bursts and, as in the case with the adult Ascidia, in this way the sanguiferous fluid accumulated in the hollow muscular tube is driven in all directions into the blood-vessels, which develop at both ends of the aortic tube. One principal vessel runs along the dorsal side of the gut, another along its ventral side. The former corresponds to the aorta and the dorsal vessel in the worms. The other corresponds to the subintestinal vein and the ventral vessel of the worms.

With the formation of these organs the progressive development of the Ascidia comes to an end, and degeneration sets in. The free-swimming larva settles to the floor of the sea, abandons its locomotive habits, and attaches itself to stones, marine plants, mussel-shells, corals, and other objects; this is done with the part of the body that was foremost in movement. The attachment is effected by a number of out-growths, usually three, which can be seen even in the free-swimming larva. The tail is lost, as there is no further use for it. It undergoes a fatty degeneration, and disappears with the chorda dorsalis. The tailless body changes into an unsightly tube, and, by the atrophy of some parts and the modification of others, gradually

assumes the appearance we have already described.

Among the living Tunicates there is a very interesting group of small animals that remain throughout life at the stage of development of the tailed, free Ascidian larva, and swim about briskly in the sea by means of their broad ear-tail. These are the remarkable *Copepoda* (*Aspochelone*).



FIG. 205.—An *Aspochelone* (Dipteristia, sea from the lake). *a*, antennae; *b*, branched gut; *c*, gills; *d*, stomach; *e*, anus; *f*, brain (situated above the gills); *g*, sensory tentacles; *h*, colored groove under the gills; *i*, heart; *j*, tentacles; *k*, ovary; *l*, chorion; *m*, tail.

aspid and *Fertiliser*, Fig. 205). They are the only living Vertebrates that have throughout life a chorda dorsalis and a second string above it, the latter must be regarded as the prolongation of the cerebral ganglion and the equivalent of the medullary tube. Their branchial gut also opens directly outwards by a pair of

branchial clefts. These instructive Cephalopods, comparable to permanent Annelids-larvae, come next to the extinct Procheroneutes, those ancient worms which we must regard as the common ancestors of the Tunicates and Vertebrates. The notochord of the Appendicularia is a long, cylindrical string (Fig. 203 c), and serves as anskeleton for the muscles that work the flat ear-tail.

Among the various modifications which the *Ascidia*-larva undergoes after its establishment at the sea-floor, the most interesting (after the loss of the axial rod) is the atrophy of one of its chief organs, the respiratory tube. In the Amphioxus the spinal marrow continues to develop, but in the *Ascidia* the tube soon shrinks into a small and insignificant nervous ganglion that lies above the mouth and the gill-clefts, and is in accord with the extremely slight mental power of the animal. This insignificant relic of the respiratory tube seems to be quite beyond comparison with the nervous centre of the vertebrates, yet is started from the same structure as the spinal cord of the Amphioxus. The sense-organs that had been developed in the fore part of the neural tube are also lost; no trace of them can be found in the adult *Ascidia*. On the other hand, the alimentary canal becomes a more extensive organ. It divides presently into two sections—a wide fore or branchial gut that serves for respiration, and a narrower hind or hepatic gut that accomplishes digestion. The branchial or head-gut of the *Ascidia* is small at first, and opens directly outwards only by a couple of lateral ducts or gill-clefts—a permanent arrangement in the Cephalopods. The gill-clefts are developed in the same way as in the Amphioxus.

under greatly a large gill-cleft, paired like lat work. In the middle line of its ventral side we find the hypobranchial gut. The mouth or stomodaeum (the stomach) that surrounds the gill-clefts is also

formed in the same way in the *Ascidia* as in the Amphioxus. The splanchnic cavity of this peribranchial cavity corresponds to the branchial pore of the Amphioxus. In the adult *Ascidia* the branchial gut and the heart on its ventral side are almost the only organs that recall the original affinity with the vertebral.

The further development of the *Ascidia* in detail has no particular interest for us, and we will not go into it. The chief result that we obtain from its embryology is the complete agreement with that of the Amphioxus in the earliest and most important embryonic stages. They do not begin to diverge until after the medullary tube and alimentary canal, and the axial rod with the muscles between the two, have been formed. The Amphioxus continues to advance, and resembles the embryonic forms of the higher vertebrates; the *Ascidia* degenerates more and more, and at last, in its adult condition, has the appearance of a very imperfect invertebrate.

If we now look back on all the remarkable features we have encountered in the structure and the embryonic development of the Amphioxus and the *Ascidia*, and compare them with the features of man's embryonic development which we have previously studied, it will be clear that I have not exaggerated the importance of these very interesting animals. It is evident that the Amphioxus from the vertebrate side and the *Ascidia* from the invertebrate form the bridge by which we can span the deep gulf that separates the two great divisions of the animal kingdom. The radical agreement of the lancelet and the sea-squid in the first and most important stages of development shows something more than their affinity and their proximity in classification, it shows a of blood-relationship and their (a) though considerable light on the distant roots of man's genealogical tree.

CHAPTER XVIII.

DURATION OF THE HISTORY OF OUR STEM

Our comparative investigation of the anatomy and ontogeny of the Amphioxus and Ascidia has given us undoubtedly assistance. We have, in the first place, bridged the wide gulf that has existed up to the present between the Vertebrates and Invertebrates; and, in the second place, we have discovered in the embryology of the Amphioxus a number of ancient evolutionary stages that have long since disappeared from human embryology, and have been lost, in virtue of the law of correlated heredity. The chief of these stages are the spherical blastula (in its simplest primary form) and the succeeding archegastrula, the pure, original form of the gastrula which the Amphioxus has preserved to this day, and which we find in the same form in a number of Echinoderms of various classes. Not less important are the later embryonic forms of the notula, the chorula, etc.

Thus the embryology of the Amphioxus and the Ascidia has so much increased our knowledge of man's stem-history that, although our ontological information is still very incomplete, there is now no defect of any great consequence in it. We may now, therefore, approach our proper task, and reconstruct the phylogeny of man in his chief lines with the aid of this evidence of comparative anatomy and ontogeny. In this the reader will soon see the immense importance of the direct application of the biogenetic law. But before we enter upon the work it will be useful to make a few general observations that are necessary to understand the processes afloat.

We must say a few words with regard to the period in which the human race was evolved from the animal kingdom. The first thought that occurs to one in

between the duration of man's ontogeny and phylogeny. The individual needs only nine months for his complete development, from the fertilization of the ovum to the moment when he leaves the maternal womb. The human embryo sees its whole origin in the brief space of

sixty weeks (as a rule, six days). In many other mammals the time of the embryonic development is much the same as in man—for instance, in the cow. In the horse and man it takes a little longer, forty-three to forty-five weeks, in the camel, thirteen months. In the largest mammals, the embryo needs a much longer period for its development in the womb—a year and a half in the rhinoceros, and nearly two in the elephant. In these cases pregnancy lasts twice as long as in the case of man, or one and three-quarter years. In the smaller mammals the embryonic period is much shorter. The smallest mammals, the dwarf-mice, develop in three weeks; hares in four weeks, rats and shrews in five weeks, the dog in nine, the pig in seventeen, the sheep in twenty-six and the goat in thirty-six. Birds develop still more quickly. The chick only needs, in normal circumstances, three weeks for its full development. The duck needs twenty-five days, the turkey twenty-seven, the guinea-fowl thirty-one, the swan forty-two, and the cassowary sixty-five. The smallest bird, the humming-bird, leaves the egg after twelve days. Hence the duration of individual development within the fetal membranes is, in the mammals and birds, closely related to the absolute size of the body of the animal in question. But this is not the only determining feature. There are a number of other circumstances that have an influence on the period of embryonic development. In the Amphioxus the earliest and most important embryonic processes take place so rapidly that the blastula is formed in four hours, the gastrula in six, and the typical vertebrate form in twenty-four.

In every case the duration of ontogeny

is in part it with the enormous period that has been necessary for phylogeny, or the gradual development of the structural series. This period is not measured by years or centuries, but by thousands and millions of years. Many millions of years had to pass before the most advanced

vertebrate, man, was evolved, step by step, from his ancient invertebrate ancestor. The appearance of evolution, when darkness the gradual development of the human form from lower animal forms, and ultimately from a vertebrate organism, is an inevitable result, deeper than the same relative ideas given under the aspect of such mistakes as the earlier the development of every human being. Each of us has, in the first, origin (properly speaking, in the first few weeks of the development of the embryo, passed through the same series of transformations that our nearest ancestors underwent in the course of millions of years.

It is impossible to guarantee even approximately, in hundreds or even thousands of years, the real and absolute duration of the phylogenetic period. But for some time now we have, through the research of geologists, been in a position to assign the relative length of the various periods of the organic history of the earth. The latest and best for determining the relative length of the geological periods are found in the conclusion of the geographers' work—the work that has been done on the basis of the use of a few years from the end of the last geological period. These geological periods of formation, sedimentation, etc., etc., which made up the greater part of the earth, and are also covered, changed by the sea, give us a standard for measuring the relative length of the various periods.

To make the point quite clear, I would say a word about the evolution of the earth in general, and point out briefly the chief features of the story. In the first place, we remember the principle that on our planet water life began to exist in a definite period. That statement is no longer disputed by any competent geologist or biologist. The organic history of the earth could not commence until it was possible for water to exist on our planet in fluid condition. Every organism without exception, needs fluid water as a condition of existence, and therefore a considerable quantity of it. Our own body, when fully formed, contains water to seventy per cent of water in its tissues, and only thirty to forty per cent of solid matter. There is even more water in the body of the child, and still more in the embryo. In the earlier stages of development the human foetus contains more than ninety per cent of water, and not less per cent of solids. In the lower marine animals,

especially certain molluscs, the body consists in the extent of more than ninety per cent, of sea water, and has not even one part of solid matter. No organism can exist or discharge its functions without water. No water, no life!

But fluid water, on which the existence of life primarily depends, could not exist on our planet until the temperature of the surface of the unconsolidated sphere had sunk to a certain point. Up to that time it remained in the form of steam. But as soon as the heat had sunk enough to be condensed from the gaseous state of steam, it began its geological action, and has continued down to the present day to modify the solid crust of the earth. The first outcome of this immense action of the water—wearing down and dissolving the rocks in the form of rain, fog, snow, and ice, as running streams or melting glaciers—in the formation of mud. As Huxley says in his admirable *Lectures on the Causes of Extinction of Organisms*, "Nature, the chief determinant of the past history of our earth is mud, the question of the history of past ages—water, mud, has a question about the formation of mud.

As I have said, it is possible to form an approximate idea of the relative age of the various periods by measuring those of different parts of the earth's surface (geologists have long been agreed that there is a definite geological succession of the different rocks). The various rocks assigned by the geologists to various periods in the organic history of the earth, as it were, they were determined by the form of mud as the basis of the age. The mud was gradually converted into stone. This was the end of the water period in connection with the earth's history, and through the succession. As a rule, but in few cases divisions are distinguished in the organic history of the earth corresponding to the larger and smaller groups of the various periods. The larger periods are then subdivided into a series of smaller ones, which usually bear some relation to life. The comparative philosophy of the groups of plants enables us to make an approximate judgment of the relative length of these various periods of time. The common measure is "in a geological system of a certain thickness (about two feet) is found in the strata; therefore, a layer of one foot thick must be given, one piece of it." Different stages of the same thickness may and very different periods for their duration. But from

DURATION OF THE HISTORY OF OUR STEM

the thickness or size of the strata we can then draw conclusions as to the relative length of the period.

The first and oldest of the four or five chief divisions of the organic history of the earth is called the primordial, archaic, or archæozoic period. If we compute the total average thickness of the sedimentary strata at about 130,000 feet, this first

(5.6) indicates—possibly 9.6. Of late years the thickness of the archaic rocks has been put at 90,000 feet.

The primordial period falls into three subordinate sections—the Laurentian, Huronian, and Cambrian, corresponding to the three chief groups of rocks which the archaic formation. The immense period during which the

SYNOPSIS OF THE PALEONTOLOGICAL FORMATIONS, OR THE FOSSILIFEROUS STRATA OF THE CRUST

V Archæozoic group <i>Archaean</i> <i>(Silurian)</i> <i>time of strata</i>	XIV Huron <i>Huronian</i> <i>(Silurian)</i> <i>time of strata</i>	XV Laurentian <i>Laurentian</i> <i>(Silurian)</i> <i>time of strata</i>	<i>Lower Silurian</i> <i>Lower Devonian</i> <i>Lower Permian</i> <i>Lower Carboniferous</i> <i>Lower Permian</i> <i>Lower Triassic</i> <i>Lower Jurassic</i> <i>Lower Cretaceous</i> <i>Lower Tertiary</i> <i>Lower Quaternary</i>
			<i>Lower Silurian</i> <i>Lower Devonian</i> <i>Lower Permian</i> <i>Lower Carboniferous</i> <i>Lower Permian</i> <i>Lower Triassic</i> <i>Lower Jurassic</i> <i>Lower Cretaceous</i> <i>Lower Tertiary</i> <i>Lower Quaternary</i>
VI Paleozoic group <i>Paleozoic</i> <i>(Silurian)</i> <i>time of strata</i>	XVI Devonian <i>Devonian</i> <i>(Silurian)</i> <i>time of strata</i>	XVII Carboniferous <i>Carboniferous</i> <i>(Silurian)</i> <i>time of strata</i>	<i>Lower Carboniferous</i> <i>Lower Permian</i> <i>Lower Triassic</i> <i>Lower Jurassic</i> <i>Lower Cretaceous</i> <i>Lower Tertiary</i> <i>Lower Quaternary</i>
			<i>Lower Carboniferous</i> <i>Lower Permian</i> <i>Lower Triassic</i> <i>Lower Jurassic</i> <i>Lower Cretaceous</i> <i>Lower Tertiary</i> <i>Lower Quaternary</i>

period comprises 70,000 feet, or the greater part of the whole. For this and other reasons we may at once conclude that the corresponding primordial or archæozoic period must have been in itself much longer than the whole of the remaining periods together, from its close to the present day. It was probably much longer than the figures I have quoted

were standing in the primitive ocean probably comprised more than 50,000,000 years. At the commencement of it the oldest and simplest organisms were formed by spontaneous generation—the *Micæra*, with which the history of life on our planet opened. From these were first developed unicellular organisms of the simplest character, the *Protophyta*

in the Jurassic, and none in the Cretaceous. All the mammals remain that we have from this section belong to the lower proto-mammals and marsupials; among these were most certainly the ancestors of the human race. On the other hand, we have not found a single indeterminate fossil of any higher mammal in this period; in the whole of this period. This division of the mammals, which includes man, was not developed until later, towards the close of this or in the following period.

The fourth section of the organic history of the earth, the Tertiary or Cenozoic age, was much shorter than the preceding. The forms that were deposited during this period have a thickness (thickness of only about 3,000 feet. It is subdivided into four sections—the Eocene, Oligocene, Miocene, and Pliocene. During these periods there was a very rapid development of higher plants and animals during the Eocene and those of our planet approached nearer and nearer to the conditions that they bear today. In particular, the most advanced class, the mammals, began to predominate. Hence the Tertiary period may be called "the age of mammals." The highest section of this class, the placental, now made their appearance; in this group the human race belongs. The first appearance of man, or, to be more precise, the development of man from some closely-related group of apes, probably falls within the Miocene or the Pliocene period, the middle or the last section of the Tertiary period. Others believe that man properly so-called—man endowed with speech—was not evolved from the non-speaking apes (Anthropomorphs) until the following, the Anthropocene, age.

Is this fifth and last section of the organic history of the earth we have had development and deposition of various races of man, and so it is called the Anthropocene as well as the Quaternary period. Is the imperfect condition of paleontological and ethnographical science we cannot as yet give a confident answer to the question whether the evolution of the human race from some extinct ape or lower hominid class at the beginning of this or towards the middle or the end of the Tertiary period. However, this much is certain: the development of civilization falls in the Anthropocene age, and this is purely an insignificant fraction of the vast period of the whole history of life. When we

remember this, it seems ridiculous to restrict the word "history" to the civilized period. If we divide into a hundred equal parts the whole period of the history of life, from the spontaneous generation of the first life-form to the present day, and if we then represent the relative duration of the five chief sections or ages, as calculated from the average thickness of the masses they contain, no percentages of time, we get something like the following column:—

I. Archeozoic or archaic (pre-mammal) age	10 6
II. Paleozoic or paleozoic (pre-mammal) age	10 1
III. Mesozoic or mesozoic (pre-mammal) age	11 1
IV. Cenozoic or cenozoic (Tertiary) age	2 3
V. Anthropocene or anthropocene (Quaternary) age	0 3

In any case, the "historical period" is an insignificant quantity compared with the vast length of the preceding ages, in which there was no question of human civilization on our planet. Even the long Tertiary Cenozoic or Tertiary period, in which the first proto-mammals or higher mammals appear, probably amounts to little over two per cent. of the whole organic age.

Before we approach our proper task, and with the aid of our comparative zoology and the biological law follow step by step the paleontological development of our animal kingdom, let us glance for a moment at another, and apparently quite remote, branch of science, a general consideration of which will help us in the solving of a difficult problem, I mean the science of comparative philology. Since Darwin gave new life to biology by his theory of selection, and raised the question of evolution on all sides, it has often been pointed out that there is a remarkable analogy between the development of languages and the evolution of species. The comparison is perfectly just and very instructive. We cannot hardly find a better analogy which we are dealing with some of the difficult and obscure features of the evolution of species. In both cases we find the action of the same natural law.

All philologists of any consequence in their science now agree that all known languages have been gradually evolved from very rudimentary beginnings. The

idea that speech is a gift of the gods—an idea held by distinguished authorities only fifty years ago—is now generally abandoned, and only supported by linguists and others who admit no rational development of language. Speech has been developed simultaneously with no organ, the larynx and tongue, and with the functions of the brain. Hence it will be quite natural to find in the evolution and classification of languages the same features as in the evolution and classification of organic species. The various groups of languages that are distinguished in philology as primitive, long-stemmed, parent, and daughter languages, dialects, etc. correspond entirely to their development in the different categories in which we classify as living, and dying; as young, old, extinct, certain, uncertain, common, unique, and variation. The relation of these groups, partly co-extensive and partly subordinate in the general system is just the same in both cases, and the evolution follows the same lines in both.

When, with the assistance of this key, we follow the formation of the various languages that have been developed from the common root of the ancient Indo-Germanic tongue, we get a very clear idea of their phylogeny. We find, first, at the same time how analogous this is to the development of the various groups of vertebrates that have arisen from the common stem-form of the primitive vertebrate. The ancient Indo-Germanic language divided first into two principal stems, the *Slavo-Germanic* and the *Aryo-Hittite*. The *Slavo-Germanic* then divided into the eastern *Germanic* and the western *Slavo-Latvian* groups, the *Aryo-Hittite* into the ancient *Aryan* and the ancient *Græco-Hittite*. We will follow the genealogical tree of these four Indo-Germanic tongues, we find that the ancient *Germanic* divides into three branches, the *Scandinavian*, the *German*, and the *Low-German*. From the ancient *German* came the *High German* and *Low German*, the latter being the *Prussian*, *Polish*, and modern *Low-German* dialects. The ancient *Slavo-Latvian* divided first into a *Slavic* and a *Latvian* language. The *Slavic* gave rise to the *Latvian*, *Lithuanian*, and old-*Prussian* varieties, the *Slav* to the *Russian* and *South-Slav* in the south-east, and to the *Polish* and *Czech* in the west.

We find an equally parallel branching of the tree of the stems when we begin to

the other division of the Indo-Germanic languages. The *Græco-Hittite* divided into the *Thracian* (*Athens-Greek*) and the *Indo-Celtic*. From the latter came the divergent branches of the *Indic* (*Hindu* and *Celtic*) in the north, and the *Celtic* in the north from the latter have been developed all the *British* (*British*, *Irish*, and *Welsh*) and *Latin* varieties. The ancient *Aryan* gave rise to the numerous *Low* and *High* languages.

The "comparative anatomy" and evolution of languages admirably illustrates the phylogeny of species. It is clear that in structure and development the primitive languages, mother and daughter languages, and varieties correspond exactly to the classes, orders, families, and species of the animal world. In both cases the "species" system is phylogenetic. As we have been convinced from comparative anatomy and embryology, and from palæontology, that all past and living vertebrate animals have a common ancestor, so the comparative study of dead and living Indo-Germanic tongues proves beyond question that they are all modifications of one primitive language. This view of their origin is now accepted by all the chief philologists who have worked in this branch and are unopposed.

But the point to which I desire particularly to draw the reader's attention is the comparison of the Indo-Germanic languages with the structure of the vertebrate stem, that one must never confuse direct development with collateral branches, and direct development with living. This confusion is very common, and our opponents often make use of the confusion when it gives rise to the purpose of attacking or otherwise generally. When, for instance, we say that some descend from the ape, this does not mean, and the latter from the monkey, many people imagine that we are speaking of the living species of these orders of mammals that they had stuffed in our museums. Our opponents think that this idea is an, and say, with much satisfaction, that intelligence, that it is quite impossible; or they ask us, by way of physiological experiment, to turn a language into a lower, a lower into a higher, and a higher into a man! This demand is absurd, and the idea it rests on erroneous. All these living forms have changed more or less from the mammalian stem; none of them could surrender the

many probably that the stem-form really produced thousands of years ago.

It is certain that man has descended from some extinct mammal; and we should just as certainly class this in the order of ages if we had it before us. It is equally certain that this primitive ancestor is here from an unknown lower, and this from an extinct mammal. But it is just as clear that all these extinct ancestral forms can only be claimed as belonging to the living order of mammals in virtue of their assumed internal structure and their resemblance to the decisive mammalian characteristics of each order in external appearance in the characteristics of the genus or species, they would differ more or less, perhaps very considerably, from all living representatives of these orders. It is a natural and natural procedure in phylogenetic development that the stem-forms degenerate, and in this sense the postulations, have been subject for some time. The forms that approach nearest to man among the living species are more or less — perhaps very substantially — different from them. Hence in our phylogenetic inquiry and in the comparative study of the living, divergent descendants, there can only be a question of determining the greater or less remoteness of the latter from the ancestral form. Not a single one of the older stem-forms has continued unchanged down to our time.

We find just the same thing in considering the various dead and living languages that have developed from a common primitive tongue. If we examine our genealogical tree of the Indo-European languages in this light, we see at once that all the older or parent tongues of which we regard the living varieties of the stem as divergent daughter or grand-daughter languages, have been extinct for some time. The Arya-Remania and the Sino-Chinese tongues have completely disappeared; so also the Aryan, the Uro-Aryan, the Sino-Latin, and the ancient Germanic. Even their daughters and grand-daughters have been lost; all the living Indo-European languages are only related in the sense that they are divergent descendants of common stem-forms. Some forms have diverged more, and some less, from the original stem-form.

This easily demonstrates that Huxley's very well the analogous case of the origin of the vertebrate species. Flying-squirrels

comparative philology have yielded a strong support to phylogenetic comparative zoology. But the one can adduce more direct evidence than the other, as the paleontological material of philology — the old manuscripts of the extinct languages — have been preserved much better than the paleontological material of zoology, the fossilized bones and imprints of vertebrates.

We may, however, take man's progenitor not only as far as the lower mammals, but much farther — to the amphibia, to the shark-like primitive fishes, and, in fact, to the step-like vertebrates that closely resembled the Amphioxus. But this must not be understood in the sense that the so-called Amphioxus, or the sharks or amphibia of to-day, can give us any idea of the ancestral appearance of these remote stem-forms. Still less must it be thought that the Amphioxus or any other shark, or any living species of amphibia, is a real ancestral form of the higher vertebrates and man. The statements can only rationally mean that the living forms I have referred to are *analogous* to those that are much more remotely related to the extinct stem-forms, and have retained the resemblance much more, than any other animals we know. They are not so like them in regard to their *fundamental* internal structure that we should put them in the same class with the extinct forms if we had direct before us. But we direct descendants of these earlier forms have remained unchanged. Hence we must certainly abandon the idea of finding direct evidence of the historic root in their characteristic *external* form among the living species of animals. The essential and distinctive features that still connect living forms more or less closely with the extinct common stem-forms lie in the internal structure, not the external appearance. The latter has been much modified by adaptation. The former has been more or less preserved by heredity.

Comparative anatomy and zoology prove beyond question that man is a true vertebrate, and, therefore, man's special genealogical tree must be connected with that of the other Vertebrates, which spring from a common root with him. But we have also many important grounds in comparative anatomy and zoology for assuming a common origin for all the Vertebrates. If the general theory of

evolution is current, all the Vertebrates, including man, arose from a single common ancestor, a long-voiced "Primitive Vertebrate." Hence the genealogical line of the Vertebrates is at the same time that of the human race.

Our task, therefore, of constructing man's genealogy, including the larger aim of discovering the genealogy of the entire terrestrial stem. As we now know from the comparative anatomy and embryology of the Amphibians and the Reptiles, that it is first connected with the genealogical line of the Invertebrates (directly with that of the Vermes), but has no direct connection with the independent stems of the Arthropods, Molluscs, and Echinoderms. If we do thus follow our ancestral line through various stages down to the lowest worms, we come lastly, lastly to the Gastrea, that most instructive form that gives the clearest possible picture of an animal with two germinal layers. The latter can well not originate from the simple multicellular animals, the *Alveolates* and then to have been evolved from the lower grade of multicellular animals, to which we give the name of *Protoplasms*. We have already considered the most important primitive type of them, the multicellular *Alveolates*, which is especially instructive when compared with the higher forms. With this we reach the lowest of the solid forms to which we are to apply the biological law, and by which we may define the entire animal from the embryonic form. The specialized nature of the young worm and the multicellular condition in which (as shown-cell or crystal) every human being begins his existence justify us in affirming that the earliest ancestors of the human race were simple crystalline cells.

But the further question now arises: "Whence came these first animals with which the history of life begins at the commencement of the Laurentian epoch?" There is only one answer to this. The earliest multicellular organisms are only known to have evolved from the simplest organisms we know, the *Alveolates*. These are the simplest living things that we are ourselves. Their whole body is nothing but a particle of plasma, a granule of living albuminous matter, discharging of itself all the essential vital functions that form the material basis of life. Thus we come to the last, or, if you prefer, the first, question in connection with evolution—the question of the origin of the human

This is the real question of the origin of life, or of spontaneous generation.

We have further space for comment to go further in this Chapter into the question of spontaneous generation. For this I must refer the reader to the following chapters of the *History of Creation*, and especially to the second book of the *General Morphology*, or to the essay on "The Structure and Spontaneous Generation" in my *Handbook of the History and other Problems*. I have given there fully my own view of this important question. The famous French biologist *Agassiz* (1813) developed the same ideas. I will only say a few words here about this obscure question of the origin of life, in so far as our main subject, organic evolution is concerned, is affected by it. Spontaneous generation, in the technical and restricted sense in which I maintain it, and show that it is a necessary hypothesis in explaining the origin of life, refers solely to the creation of the history, from independent organisms upwards. When living things arise that first appear on our planet, the very simplest multicellular organisms of nature that we call *Alveolates*, which at the earliest stage of development of solid nature, must have been formed in a purely chemical way from inorganic carbon compounds. The first *Alveolates* must therefore be the first spontaneous generation, as organisms are formed in the further order. Our demand for a logical order of organic evolution as to nature (life), if we believe that the whole inorganic history of the earth has proceeded in accordance with principles without any intervention of a Cause, and that the history of life also has been determined by the same mechanical laws. If we are then able to explain the origin of the various groups of organisms; it is strictly logical to assume such creative action in dealing with the first appearance of organic life on the earth.

This much-disputed question of "spontaneous generation" seems so obscure, because people have associated with the term a mass of very different, and often very absurd, ideas, and have attempted to solve the difficulty by the crudest experiments. The real doctrine of the spontaneous generation of life cannot possibly be refuted by experiments.

* The English reader will find a history and explanation of the origin of life, in my *Handbook of the History and other Problems*, pp. 1-100.

Every experiment that has a negative result only proves that no organism has been formed out of inorganic matter in the conditions—highly artificial conditions—we have established. On the other hand, it would be exceedingly difficult to prove the theory by way of experiment; and even if Monera were still formed daily by spontaneous generation (which is quite possible), it would be very difficult, if not impossible, to find a solid proof of it. Those who will not admit the spontaneous generation of the first living things in our sense must have recourse to a supernatural miracle; and this is, as a matter of fact, the desperate resource to which our "exact" microscopists

recourse.

A famous English physicist, Lord Kelvin (then Sir W. Thomson), attempted to dispense with the hypothesis of spontaneous generation by assuming that the organic inhabitants of the earth were developed from germs that came from the inhabitants of other planets, and that chance led to fall on our planet on fragments of their original forms, or meteorites. This hypothesis found many supporters, among others the distinguished German physicist, Helmholtz. However, it was refuted in 1872 by the able physicist, Friedrich Zöllner, of Leipzig, in his work,

On the Nature of Comets. He showed clearly how unscientific this hypothesis is; firstly in point of logic, and secondly in point of scientific content. At the same time he pointed out that our hypothesis of spontaneous generation is "a necessary condition for understanding nature according to the law of causality."

I repeat that we must call in the aid of the hypothesis only as regards the Monera, the structureless "organisms without organs." Every complex organism must have been evolved from some lower organisms. We must not assume the spontaneous generation of even the simplest cell, for this itself consists of at least two parts—the internal, first nuclear substance, and the external, softer cellular substance or the protoplasm of the cell-body. These two parts must have been formed by differentiation from the indifferently plastic of a moneron, or a cytode. For this reason the natural history of the Monera is of great interest: here alone can we find the means to overcome the chief difficulties of the problem of spontaneous generation. The actual living Monera are specimens of such organless or structureless organisms, as they must have been formed by spontaneous generation at the commencement of the history of life.

CHAPTER XIX.

OUR PROTIST ANCESTORS

Under the guidance of the biogenetic law, and on the basis of the evidence we

may find in the
Physiogenetic

as a whole is an inductive process, the totality of the biological processes in the life of plants, animals, and man we have gathered a confident inductive idea that the whole organic population of our planet has been moulded on a harmonious law of evolution. All the interesting

phenomena that we meet in ontogeny and paleontology, comparative anatomy and cytology, the distribution and habits of organisms—all the important general laws that we abstract from the phenomena of these sciences, and combine in harmonious unity—are the broad bases of our great biological induction.

But when we come to the application of this law, and seek to determine with its aid the origin of the various species of organisms, we are compelled to frame

hypotheses that have essentially a didactic character, and are inferrable from the general law to particular cases. But these special deductions are just as much justified and substantiated by the rigorous laws of logic as the inductive inductions on which the whole theory of evolution is based. The doctrine of the natural symmetry of the human mind is a special deduction of this kind and follows with logical necessity from the general induction-law of evolution.

I must point out at once, however, that the symmetry of these evolutionary hypotheses, which rest on quite special deductions, is not always equally strong. Some of these inductions are more far-reaching, in the order of degree it depends on the type of type and the antiquity of the material whose degree of antiquity he perceives as them in any way, so many distinguish between the absolute symmetry of the general (inductive) theory of descent and the relative symmetry of special (deductive) evolutionary hypotheses. We can now determine the whole material scope of an argument with the same confidence with which we hold the general theory of evolution as the sole scientific explanation of organic development. The special deductions of such facts in detail will always be more or less incomplete and by practical. This is quite natural. The evidence on which we build is imperfect, and always will be imperfect, just as in deductive philosophy.

The field of our deductive paleontology is accordingly incomplete. We know that all the fossils we discovered are only an insignificant fraction of the plants and animals that have lived on our planet. For everything appears that has been preserved for us in the rocks there are probably hundreds, perhaps thousands, of other species that have left no trace behind them. This evidence and very extraordinary incompleteness of the paleontological evidence, which cannot be pointed out too often, is easily explained. It is obviously very rare in the circumstances of the development of organisms. It is due in part to the incompleteness of our knowledge in this branch. It must be borne in mind that the great majority of the structural units that compose the crust of the earth have not yet been opened. We have only a few specimens of the innumerable fossils that are buried in the vast mountain ranges of Asia and Africa.

Only a part of Europe and North America has been investigated specially. The whole of the fossil fauna is so certainly do not amount to a hundredth part of the remains that are really buried in the crust of the earth. We may, therefore, look forward on a rich harvest in the future on which this science. However, our paleontological evidence will for reasons that I have fully explained in the seventh chapter of the *History of Creation* always be defective.

The second chief source of evidence, anatomy, is not less incomplete. It is the most important source of all for special phylogeny; but it has great defects, and often fails us. We must, above all, clearly distinguish between paleontology and comparative anatomy. We must again repeat that the laws of correlation and structural heredity often make the original course of development almost unrecognizable. The reconstruction of phylogeny by anatomy is only fairly complete in a few cases, and is never whole complete. As a rule, it is primarily the external and most important characteristics that suffer most from a systematic and reconstruction. The systematists who have had to adopt Darwinism to new correlations, and so have been misled. The struggle for existence has not yet so profound an influence on the truly divergent and still extensive young forms as on the much later. Hence in the phylogeny of the higher animals, especially, paleontology is much less aided by comparative anatomy than it is today, as a rule, only a few and much altered portions of the original relations of the animal's anatomy. We can only draw conclusions from the embryonic forms to the post-embryonic with the greatest caution and circumspection. However the embryonic development itself has only been fairly studied in a few species.

Finally, the third and most valuable source of evidence, comparative anatomy, is also, unfortunately, very imperfect; for the simple reason that the whole of the living species of animals are a small fraction of the vast population that has lived on our planet since the beginning of life. We very evidently put the total number of those at more than a million upon. The number of animals whose comparative anatomy has been studied up to the present is comparatively meagre in proportionally very small. Hence, again, future research will yield innumerable specimens.

But, for the present, in view of this general incompleteness of our chief sources of evidence, we must naturally be careful not to lay too much stress on human phylogeny, on the particular animals we have studied, or regard all the various stages of development with equal importance.

In my first efforts to construct the system of man's ancestors I drew up a list of, at first ten, afterwards twenty to thirty, forms that may be regarded more or less certainly as animal ancestors of the human race, or as stages that in a sense mark off the chief divisions in the long story of evolution from the earliest organism to man. Of these twenty to thirty stages, ten to fifteen belong to the older group of the lower invertebrates and eighteen to twenty to the younger division of the Vertebrates.

In approaching, now, the difficult task of establishing the evolutionary relationships of these thirty ancestors of humanity since the beginning of life, and in venturing to list the list that covers the earliest secrets of the earth's history, we must undoubtedly begin for the first in our journey among the wonderful organisms that we call the Monera; they are the simplest organisms known to us—in fact, the simplest we can conceive. These a hole body consists merely of a vesicle furnished or gladdened of structural elements or phloem. The

distinction between the phloem of the cytosol and the protoplasm of the cells. This distinction is of the utmost importance for the purposes of evolution. As I have often said, we must recognize two different stages of development in these "elementary

organisms," or plants ("builders"), that represent the ultimate roots of organic individuality. The earlier and lower stage are the unmechanized systems, the body of which consists of only one kind of structural matter—the homogeneous phloem or "fermentary matter." The later and higher stage are the mechanized cells, in which we find a differentiation of the original phloem into two different formative substances—the cytoplasm of the nucleus and the cytoplasm of the body of the cell (cf. pp. 97 and 98).

The Monera are permanent; they retain their character of self-sustaining system. However carefully we examine it with our finest chemical reagents and most powerful microscopes,



FIG. 14.—*Chlorococcoid* (Thallo) organism. A photograph of the whole structure of each organism. The cytoplasmic structure of the whole organism. The cytoplasmic structure of the whole organism. The cytoplasmic structure of the whole organism. The cytoplasmic structure of the whole organism.

the structure of the last four decades have led us to believe with increasing certainty that whatever a natural body exhibits the vital processes of nutrition, reproduction, voluntary movement, and sensation, we have the notion of a living organism. The structure of the chemical group of the Monera, then, phloem (or protoplasm) is the material basis of all vital functions. Whether we regarded the function, in the Monera, as the direct action of the material substance, or whether we take matter and form to be distinct things on the dualistic view, it is certain that we have not except found any living organism in which the nucleus of the vital functions is not inseparably bound up with phloem.

The soft silvery phloem of the body of the Monera is generally called "protoplasm," and identified with the cellular matter of the ordinary plant and animal cells. But we must, to be accurate,

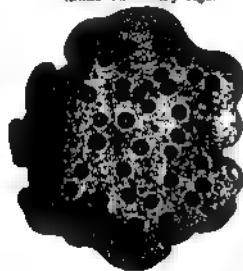
we can find no definite parts or no definite structure to it. Hence the Monera are literally organisms without organs; in fact, from the philosophic point of view they are not organisms at all, since they have no organs. They can only be called organisms on the name that they are capable of the vital functions of nutrition, reproduction, sensation, and movement. If we were to try to imagine the simplest possible organism, we should have something like the Monera.

The Monera that we find to-day in various forms fall into two groups according to the nature of their nutrition—the Phytomonera and the Zoomonera, from the physiological point of view, the former are the simplest organisms of the plant (phloem) kingdom, and the latter of the animal (flesh) world. The Phytomonera, especially in their simplest form, the Chlorococcoid (Phytomonera or Cyanophloem), are the most primitive and the

oldest of living organisms. The typical genus *Chlorella* (Fig. 126) is represented by several fresh-water species, and often forms a very delicate bluish-green deposit on wood in ponds and ditches.

..... of round, light green particles, from of an inch in diameter.

The whole life of these homogeneous globules of plasma consists of simple growth and reproduction by cleavage. When the tiny particle has reached certain size by the continuous addition of inorganic matter, it divides equally halves, by a constriction middle. The two daughter formed immediately begin



of green alga

similar vital process. It is the same with the brown *Prorocentrum minimum* (formerly called the *Prorocentrum marinoi*); it forms large masses of floating matter in the Arctic seas. The tiny plasma-globules of species are of a greenish-brown colour, of an mile.

the simplest *Chlorellaceae*, but we find one in other members of the same family; in *Aphanizomenon* (Fig. 127) the enveloping all the phloids in *Gleocystis* they are retained through several generations, so that the little plasma-globules are embedded in many layers of murein.

Next to the *Chlorellaceae* come the *Bacteria*, which have been evolved from them by the remarkable change in nutrition which gives us the simple explanation of the difference of plant

the protist kingdom. The *Chlorellae* build up their plasma directly from organic matter; the *Bacteria* feed on organic matter. Hence, if we logically divide the protist kingdom into plasma-forming *Protophytes* and plasma-consuming *Protophages*, we must class the *Bacteria* with the latter; it is quite illogical to describe them—as is still often done—as *Sakomys* and class them with the true fungi. The *Bacteria*, like the *Chlorellae*, have no nucleus. As is well known, they play an important part in modern biology as the causes of fermentation and putrefaction, and of tuberculosis, typhus, cholera, and other infectious diseases, and as parasites, etc. But we cannot linger now to deal with those very interesting features; the *Bacteria* have no relation to man's genealogical tree.

We now turn to consider the remarkable *Protamoeba*, or unencapsulated *Amoeba*. I have, in the first volume, pointed out the great importance of the ordinary *Amoeba* in connection with several exciting questions of general biology. The (i) *Protamoeba*, which we found both in fresh and salt water, have the more unshapely form and irregular movements of their simple ovoid body as the real *Amoeba*, but they differ from them very materially in having no nucleus in their cell-body.

The short, blunt, finger-like processes that are thrust out at the surface of the creeping *Protamoeba* serve for grasping food as well as for locomotion. They multiply by simple cleavage (Fig. 128).

The next stage is the simple cytodifferentiation of the *Monera* in the genealogy of animals (and all other animals) is the simple cell, or the most rudimentary form of the cell which we find living independently to-day as the *Amoeba*. The earliest process of inorganic differentiation in the structureless body of the *Monera* led to into two different substances—the *cytoplasma* and the *cytoplasm*. The *cytoplasma* is the inner and firmer part of the cell, the substance of the nucleus. The *cytoplasm* is the outer and softer part, the substance of the body of the cell. By this important differentiation of the plasma into nucleus and cell-body, the

organized cell was evolved from the structureless cytozoa, the nucleated from the un-nucleated plasmid. Thus the first cells to appear on the earth were formed from the Monera by such a differentiation scheme as to the only possible view in the present condition of science. We have a direct instance of this earliest process of differentiation to-day in the ontogeny of many of the lower Protists (such as the *Gracilaria*).

The unicellular form that we have in the ovum has already been described as the reproduction of a corresponding unicellular stem-form, and as this we have described the organization of an *Amoeba* (cf. Chapter VI.). The irregular-shaped *Amoeba*, which we find living independently to-day in our fresh and salt water, is the least definite and the most primitive of all (Fig. 14).

the unripe one (the problem that we find in the ovum of animals) cannot be distinguished from the common *Amoeba*, we must regard the *Amoeba* as the primitive form that is reproduced in the embryonic stage of the amoeboid ovum to-day, in accordance with the biogenetic law. I have already pointed out, as proof of the striking resemblance of the cells, that the ova of many of the sponges were formerly regarded as primitive *Amoeba* (Fig. 18). Large unicellular organisms like

Amoeba were found creeping about inside the body of the sponge, and were thought to be parasites. It was afterwards discovered that they were really those of the sponge from which the embryos were developed. As a of fact, these sponge-ova are so common like many of the *Amoeba* in size, shape, the character of their surface, and movement of the pseudopodia. That it is impossible to distinguish them without knowing their subsequent development.

relation of the of it to some

not associated un-nucleated form, supply the answer to the old problem: "What was first, the egg or the chick?" We can now give a very plain answer to this riddle, with which our opponents have often tried to drive us into a corner. The egg came a long time before the chick. We do not mean, of course, that the egg existed from the first as a bird's egg, but as an indifferent amoeboid cell of the simplest character. The egg lived for thousands of years as an independent

unicellular organism, the *Amoeba*. The egg, in the modern physiological sense of the word, did not make its appearance until the descendants of the unicellular Protist had developed into multicellular animals, and these had undergone sexual differentiation. Even then the egg was first a gamete-egg, then a platode-egg, then a trophic-egg, and chorion-egg; later still acrozo-egg, then fish-egg, amphibian-egg, reptile-egg, and finally bird's egg. The bird's egg we have as a product of daily is a highly complicated

product, the result of countless hereditary processes that have taken place of years

The simple Protophyta, and from them our protistic ancestors were developed after the morphological point of view both the vegetal and the animal Protists were simple organisms, id-



FIG. 14. A young *Amoeba* (Protophyta) - the first of reproduction. A The whole organism, moving like an amoeba, capable of changing its shape. B The first division of the organism into two cells. C The first division of the organism into two cells. D The first division of the organism into two cells. E The first division of the organism into two cells. F The first division of the organism into two cells. G The first division of the organism into two cells. H The first division of the organism into two cells. I The first division of the organism into two cells. J The first division of the organism into two cells. K The first division of the organism into two cells. L The first division of the organism into two cells. M The first division of the organism into two cells. N The first division of the organism into two cells. O The first division of the organism into two cells. P The first division of the organism into two cells. Q The first division of the organism into two cells. R The first division of the organism into two cells. S The first division of the organism into two cells. T The first division of the organism into two cells. U The first division of the organism into two cells. V The first division of the organism into two cells. W The first division of the organism into two cells. X The first division of the organism into two cells. Y The first division of the organism into two cells. Z The first division of the organism into two cells.

classification of the first order, or phyla. The descendants are described as individuals of a higher order - social aggregations of a plurality of cells. The earliest of these, the *Amoeba*, which represent the third stage in our genealogy, are very simple associations of homogeneous, indifferent cells - undifferentiated colonies of social *Amoeba* or Infusoria. To understand the nature and origin of these prot-

we follow step by step the first embryonic products of the stem-cell. In all the instances the first embryonic process is the repeated cleavage of the stem-cell, or first organization-cell (Fig. 19). We have already fully considered this process, and found that all the different forms of it may be reduced to one type, the original equal or plurifurcal segmentation (cf. Chapter VIII.). In the genealogical tree

of the Vertebrates this pangenetic form of segmentation has been preserved in the *Amphioxus* alone, all the other Vertebrates having ontogenetically modified forms of cleavage. In any case, the latter were developed from the former, and so the segmentation of the ovum in the *Amphioxus* has a great interest for us (cf. Fig. 38). The outcome of this repeated cleavage is the formation of a round

small community of *Amoebae* arose by the side of these eccentric Protozoa, the sister-cells produced by cleavage remaining joined together. The advantages in the struggle for life which these communities had over the isolated cells favoured their formation and their further development. We find plenty of these cell-colonies or communities to-day in both fresh and salt water. They belong to various groups

Fig. 12. (Original or pre-embryonic) group-cleavage. The cleavage or clefts, formed by surrounding of a group, by repeated regular cleavage first into two (A), then four (B), then eight (C) and finally a large cluster of multiplicate cells (D).

cluster of cells, composed of homogeneous indifferent cells of the simplest type (Fig. 120). This is called the morula (= mulberry-embryo) on account of its resemblance to a mulberry or blackberry.

It is clear that this morula reproduces for us to-day the simple structure of the multicellular animal that succeeded the unicellular amoeboid form in the early Laurentian period, in accordance with the biogenetic law, the morula recalls the ancestral form of the *Amoeba*, or simple colony of Protozoa. The first cell-com-

of our race that succeeded phyloger

to the morula, we have only to follow the further embryonic development of the morula. We then see that the social cells of the round cluster secrete a sort of jelly or a watery fluid inside their globular body, and they themselves rise to the surface of it (Fig. 29 A, B). In this way the solid mulberry-embryo becomes a hollow sphere, the wall of which is composed of a single layer of cells. We call this layer the blastoderm, and the sphere itself the blastula, or embryonic vesicle.

This interesting blastula is very important. The conversion of the morula into a hollow ball proceeds on the same lines originally in the most diverse stems--as, for instance, in many of the *Asphyria* and *Worms*, the *Medusa*, many of the *Actinodermata* and *Mollusca*, and in the *Amphioxus*. Moreover, in the animals in which we do not find a real palaeontologic blastula the defect is clearly due to ontogenetic causes, such as the formation of food-cells and other embryonic adaptations.

We may, therefore, the ontogenetic blastula is the reproduct of a very early phylogenetic stem-form, all the Metas-

stem-form, which was in the main constructed like the blastula. In many of the lower animals the blastula is not developed



FIG. 120.—Morula, or mulberry-shaped embryo.

unities to be formed, which laid the early foundation of the higher multicellular body, must have consisted of homogeneous and simple amoeboid cells. The oldest *Amoebae* lived isolated lives, and even the amoeboid cells that were formed by the segmentation of these unicellular organisms must have continued to live independently for a long time. But gradually

while the food membrane, but in the open water. In these cases each blastodermic cell begins at an early stage to thrust out one or more mobile hair-like processes; the body swells about by the vibratory movement of these bristles or whips (Fig. 29 F).

We still find, both in the fresh water, various kinds of primitive multicellular organisms that substantially, the blastula in it may be:

1. *Uru-forms*—hollow vesicles or gelatinous balls, with a wall composed of a single layer of ciliated homogeneous cells.

There is found even among the *Phaeophyta*—the familiar *Volvocina*, formerly classed with *Infusoria*—is found in the ponds in the spring—a small, green, gelatinous globe, swimming about by means of the cilia of its bristles, which rise in pairs from the sides (Haken).

Marina viridis also, which we find in marine plankton (floating water), number of green cells form a simple ball, and the surface of the gelatinous ball; but in this case there are no cilia.

Some of the infusoria of the flagellate class (*Stigma*, *Alveophora*, etc.) are similar in structure to some vegetated clusters, but differ in their normal nutrition; they form the special group of the *Catellaria*. In September, 1893, I studied the development of one of these graceful animals on the island of Guadalupe, off the coast of Norway (*Alveophora planoides*, Figs. 231 and 232). The fully-formed body is a gelatinous ball, with its wall composed of

After reaching maturity the animal is detached. Each cell then becomes independent.

changes into a creeping animal. Afterwards contracts, and closes with a structureless membrane, then looks just like an ordinary

When it has been in this condition for some time the cell divides into two, four, eight, sixteen, thirty-two, and sixty-four cells. These arrange themselves in a round vesicle, three or four bristles, burst the capsule, and swim about in the sea.

blastula, with similar construction, of many of the lower animals, we can confidently deduce from them that there was a very early and long-extinct common stem-form of substantially the same structure—the blastula. We may call it the *Blastula*. Its body consisted, when fully formed, of a simple hollow ball, filled with fluid or structureless jelly, with a wall composed of a single stratum of ciliated cells. There were probably many genera of these

larvae, forming a special class of marine protists.

plant kingdom also the simple hollow sphere is found to be an elementary form of the multicellular organism. At the surface and below the surface (below depth of 2,000 yards) of the sea this green globe-like swimming about, with a wall composed of a single layer of chlorophyll-bearing cells. The biologist, Schrenk, gave them the name of *Heliozoa* made in 1879.

The next stage to the *Blastula*, and the next in our genealogical tree, is the *Gastrula* that is developed from it. As we have already seen, this ancestral form is particularly important. That it occurred is proved with certainty by the gastrula, which we find temporarily in the ontogeneses of all the Metazoa (Fig. 29 J, A). As we saw, the original, paleogenetic form of the gastrula is a round or oval un-lateral body, the simple cavity of which (the primitive gut) has an aperture at one pole of its axis (the primitive mouth). The wall of the gut consists of two strata of cells, and these are the primary germinal layers, the animal skin layer (ectoderm) and vegetal gut-layer (entoderm).

1. ontogenetic development of strata from the blastula furnish existence as to the phylogenetic of the Gastrula from the Blastula.

In the end this invagination goes so far as to form a deep, invaginated part of the blastoderm lies close on the inner or non-invaginated part (Fig. 29 J). In explaining the phylogenetic origin of the gastrula in the light of this ontogenetic process, we may assume that the one-layered cell-community of the blastula began to take in food more largely at one particular part of its surface. Natural selection would gradually lead to the

formation of a depression or pit at this alimentary spot on the surface of the ball. The depression would grow deeper and deeper. In time the vegetal function of taking in and digesting food would be confined to the cells that lined this hole; the

rest, that their ancestors also were phylogenetically developed from a similar sternum. This ancient stern-form is the gastraea.

The gastraea probably lived in the sea during the Cambrian period, swimming about in the water by means of its ciliary coat much as free ciliated gastrulae do to-day. Probably it differed from the existing gastrula only in one essential point, though extinct millions of years ago.

We have reason, from comparative anatomy and ontogeny, to believe that it multiplied by sexual generation, not only asexually (by cleavage, germina-



FIG. 11.—The *Stomatopora gastrula* embryo, showing about by means of the lumen or pit at the center.

other cells would see to the animal functions of locomotion, sensation, and protection. This was the first division of labour among the originally homogeneous cells of the blastula.

The effect, then, of this earliest histological differentiation was to produce two different kinds of cells—certain cells in the depression and locomotive cells on the surface outside. But this involved the reversal of the two primary germinal layers—a most important process. When we remember that in an man's body, with all its various parts, and the body of all the other higher animals, are built up originally out of these two simple layers, we cannot lay too much stress on the phylogenetic significance of this gastrulation. In the simple primitive gut or gastric cavity of the gastrula and its rudimentary mouth we have the first real organ of the animal frame in the morphological sense; all the other organs were developed afterwards from them. In reality, the whole body of the gastrula is merely a "primitive gut." I have shown already (Chapters VII. and IX.) that the two-layered embryo of all the Metazoa can be reduced to this typical gastrula. This important fact justifies me in concluding, in accordance with the biogenetic

theory, We base these hypotheses on the fact that we do to-day find the simple sexual reproduction of the gastrulae and other lower animals, exactly the gastrulae.

kind of gastrula with an oral cavity at the top of the gastrula.

There are not very many species of living gastrulae; but their morphological and phylogenetic interest is so great, an

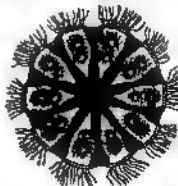


FIG. 12.—A gastrula, showing the position of the gastrula. The gastrula is shown in the center of the gastrula. Each cell has a mouth-like opening at the top of the gastrula.

their intermediate position between the Protocoon and Metacoon so instructive, that I proposed long ago (1876) to make a special class of them, I distinguished them into three classes—the Gastrularia, Phylogastrula, and Cyrenaria (or Dicyo-

mites. But we might also regard them three orders as so many independent stages in a primitive gastromed form.

The *Gastromedus* and *Cyemorus*, the chief of them living gastromeds, are small Metazoa that live parasitically inside other Metazoa, and are, as a rule, $\frac{1}{2}$ to $\frac{1}{4}$ of an inch long, often much less (Fig. 225, 2-25). Their soft body, devoid of skeleton, consists of two simple layers of cells, the primary germinal layers; the outer of these is thickly clothed with long hair-like bristles, by which the parasite upon almost in the various cavities of their host. The inner germinal layer furnishes the sexual products. The pure type of the original gastromed (or anchistomede, Fig. 225 f) is seen in the *Prostomatodermis gastromedus*, which Monod's discovered in the intestines of a large mollusk (*Paludina palustris*) in 1899. The anterior surface of this gastromedus is covered with bristles of other which, of $\frac{1}{2}$ to $\frac{1}{4}$ inch in diameter, in the head segments of which the little parasites were occurring. The cup-shaped body of the *Prostomatodermis* (Fig. 225, i) is enormous rather flat, and shaped like a hat or cone at either apex placed a curved line a semi-circle. The simple hollow of the cup, the primitive gut (g) has a narrow opening (o). The thin layer (e) consists of long slender cylindrical cells, each with long vibratory hairs. It is separated by a thin structureless gelatinous plate (j) from the middle or gut layer (f), the primitive cells of which are much smaller and have no cilia. *Prostomatodermis* propagates sexually, by single longitudinal cleavage; on this account it has recently been regarded as the representative of a special order of gastromeds (*Monodina*).

Probably a near relative of the *Prostomatodermis* in the *Kamoharui Otter* (Fig. 225, d). It lives in the intestines of *Varicella* (*Sparganium*) and differs from the former in having an outer shell on the large ventral side (e) as the small *anchistomede* (f); the germinal layers are separated by a thick, cup-shaped, gelatinous mass, which has been called the "cup vesicle" (j). The primitive mouth is surrounded by a dark ring that bears very strong and long vibratory bristles, and effects the necessary movements.

Prostomatodermis and *Kamoharui* may be included in the family of the *Gastromedus*. To these gastromeds with open gut we closely related the *Chitronomids* (*Chitronomus*, Fig. 225 2-25). They live parasitically

in the body cavity of mollusks (*Chitronomus* and *varicella*); they are distinguished by the fact that their primitive gut cavity is not empty, but filled with coelomic cells, from which the sexual cells are developed. These gastromeds are of both sexes, the male (Fig. 2) being smaller and of a somewhat different shape from the oval female (Fig. c).

The anchistomede similar *Diogenes* (Fig. 2) are distinguished from the preceding by the fact that their primitive gut cavity is occupied by a single large coelomic cell composed of a rounded group of several cells. This cell does not feed sexual products, but afterwards divides into a number of cells (several each of which, without being impregnated, grows into a small embryo. The *Diogenids* live parasitically in the body cavity especially the outer cavities of the outside surface. They fed in warm grooves, some of which are distinguished by the presence of special polar cells, the body is numerous coelomic cells, is cup-shaped, or other little long and cylindrical. The genus *Corymbus* (Fig. 2-25) differs from the ordinary *Diogenes* in having four polar points in the form of a cross, which may be important characters.

The classification of the *Cyemorus* in such important characters they are held to be parasitic in the body of the *Opisthorchus*, sometimes *plutonium* or *varicella*, related to the nuclear stage of *Opisthorchus* but having degenerated through parasitism. I adhere to the phylogenetically important theory that I advanced in 1898 that we have here the gastromeds primitive members of the numerous stem group of all the Metazoa. In the struggle for life they have found shelter in the body cavity of other animals.

The small *Chitronomids* attached to the base of the tree that I have called the *Diogenids* (*Chitronomus* and *Gastromedus*) probably have a third order for them in the living gastromeds. The genus *Chitronomus* (Fig. 225, 2-25) is certainly very similar to a large rhynchoderm (*Chitronomus*), the same name as that of the family of the *Chitronomids*, which was at first taken for a sponge. In order to avoid confusion with them, I afterwards gave them the name of *Prochitronomus*. The whole mature body of the *Prochitronomus* is a simple cylindrical or oval tube with a two-layered wall. The hollow of the tube is the gastric cavity, and the upper opening of it the mouth (Fig. 225 2-25).

The two strata of cells that form the wall of the tube are the primary germinal layers. These rudimentary zoophytes differ from the swimming polynoids chiefly in being sessile and (the end opposite the mouth) to the floor.

In *Protophytes* the peritremis is a simple oval cavity, but in the closely related *Gastrophytes* it is divided into two chambers by a transverse constriction, the hind and smaller chamber above furnishes the sexual products, the anterior one being for digestion.

The simplest sponges (*Ophion*, Fig. 231) have the same organization as the *Physarians*. The only material difference between them is that in sponges the thin two-layered body-wall is pierced by numerous pores. When these are closed they resemble the *Physaria*. Possibly the gastrulae that we call *Physarians* are only stages with the pores closed. The *Amphimedus*, or the scaphotubular sponges of the deep-sea (*Amphimedus*, etc.), do not differ from

— only zoophytes that point when

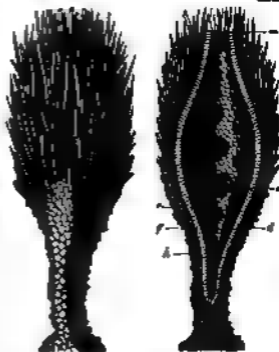


Fig. 231. *Ophion*, a living zoophyte. Fig. 232. The oldest of the *Gastrophytes* (the oldest known in the fossil record). The constriction (c) separates the anterior and posterior chambers. The pores (p) are the openings of the body-wall. The mouth (m) is the opening of the body-wall. The constriction (c) is the opening of the body-wall.

the pores are closed. In my *Monograph on the Sponges* (with sixty plates) I endeavored to prove conclusively that all the species of this class can be traced phylogenetically to a common stem-form (*Calymene*).

The lowest form of the *Cnidaria* is also not far removed from the gastrulae. In the interesting common fresh-water polyp (*Hydra*) the whole body is merely an oval tube with a double wall; only in this case the mouth has a crown of tentacles. Before these develop the hydra resembles an ascula (Figs. 236, 237). Afterwards there are slight histological differentiations in its ectoderm, though the endoderm remains



Fig. 236. *Hydra*, a *Gastrophyte*, at the end of the tube. Fig. 237. *Hydra*, at the end of the tube. The constriction (c) is the opening of the body-wall.

a single stratum of cells. We find the first differentiation of epithelial and

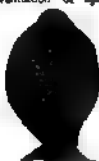


FIG. 218.—*Ptilothrix*, a very rudimentary sponge. A pure but noisy old Greek.

stinging cells, or of muscular and neural cells, in the thick ectoderm of the hydra.

In all these rudimentary living colonies the sexual cells of both kinds—ova and sperm cells—are formed by the same individual; it is possible that the oldest gastreae were hermaphroditic. It is clear from comparative anatomy that hermaphroditism—the combination of both kinds of sexual cells in one individual—as the earliest form of sexual differentiation; the separation of the sexes (gonochorism) was a much later phenomenon. The sexual cells originally proceeded from the edge of the primitive mouth of the gastrula.

CHAPTER XX.

OUR WORM-LIKE ANCESTORS

THE gastrula theory has now convinced us that all the Metazoa or multicellular animals can be traced to a common stem-form, the Gastrula. In accordance with the biogenetic law, we find solid proof of this in the fact that the two-layered embryos of all the Metazoa can be reduced to a primitive common type, the gastrula. Just as the countless species of the Metazoa do actually develop in the individual from the simple embryonic form of the gastrula, so they have all descended in past time from the common stem-form of the Gastrula. In this fact, and the fact we have already established that the Gastrula has been evolved from the hollow vesicle of the one-layered Blastula, and this again from the original unicellular stem-form, we have obtained a solid basis for our study of evolution. The clear path from the stem-cell to the gastrula represents the first section of our human stem-history (Chapters VIII., IX., and XIX.).

The second section, that leads from the Gastrula to the Prochordonia, is much more difficult and obscure. By the Prochordonia we mean the ancient and long-extinct animals which the important

embryonic form of the chordula proves to have once existed (cf. Figs. 83-85). The nearest of living animals to this embryonic structure are the lowest Tunicates, the Cephalopoda (*Appendicularia*) and the larvae of the Ascidia. As both the Tunicates and the Vertebrates develop from the same chordula, we may infer that there was a corresponding common ancestor of both stems. We may call this the Chordonia, and the corresponding stem-group the Prochordonia or Prochordula.

From this important stem-group of the unarticulated Prochordonia (or "primitive chorda-animals") the stems of the Tunicates and Vertebrates have been divergently evolved. We shall see presently how this conclusion is justified in the present condition of morphological science.

We have first to answer the difficult and much-discussed question of the development of the Chordonia from the Gastrula; in other words, "How and by what transformations were the characteristic animals, resembling the embryonic chordula, which we regard as the common stem-forms of all the Chordonia, both

Tunicates and Vertebrates, evolved from the simplest two-headed Monem? "

The descent of the Vertebrates from the Articulata has been maintained by a number of zoologists during the last thirty years with more zeal than argument; and, as a vast amount has been written on the subject, we must deal with it in some extent. All these classes of Articulata in succession have been awarded the honor of being considered the "real ancestors" of the Vertebrates; first, the Annelids (earth-worms, leeches, and the like), then the Crustacea (scorpions, etc.), and, finally, the Tracheata (spiders, insects, etc.). The most popular of these hypotheses was the annelid theory, which derived the Vertebrates from the Worms. It was advanced simultaneously (1851) independently by Carl Sauer, of Würzburg, and Anton Dohrn, of Berlin. The latter subsequently lent theory originally in favour of the falling degeneration theory, with which I join in my work, *Man and Monkeys of Modern Zoology*.

This interesting degeneration theory—first discarded at that time, but almost forgotten now—was formed in 1851 with the aim of harmonizing the results of modern and ever-advancing Darwinism with religious belief. The spirited struggle that Darwin had encountered by the reformation of the theory of descent in 1859, and that lasted for a decade with varying fortunes in every branch of biology, was drawing to a close in 1859, and came ended in the complete victory of transformation. To most of the despots of the chief point was not the general question of evolution, but the particular one of "man's place in nature"—"the question of questions," as Huxley rightly called it. It was very evident to every sane-headed thinker that this question could only be answered in the future of our anthropology, by admitting that man had descended from a long series of Vertebrates by gradual modification and improvement.

In this way the real affinity of man and the Vertebrates came to be admitted on all hands. Comparative anatomy and embryology spoke too clearly for their testimony to be ignored any longer. But in order still to save man's unique position, and especially the dignity of personal immortality, a number of natural philosophers and theologians discovered an admirable way of escape in the "theory of degeneration." Granting the affinity,

they turned the whole evolutionary theory upside down, and boldly contended that "man is not the most highly developed animal, but the simplest and degenerate man." It is true that man is clearly adapted to his age, and belongs to the vertebrate class; but the class of his ancestry goes upward instead of downward. In the beginning "God created man in his own image," as the prototype of the perfect vertebrate; not, in consequence of original sin, the human race sank so low that the ape branched off from it, and afterwards the lower Vertebrates. When this theory of degeneration was extensively developed, its supporters were bound to hold that the entire animal kingdom was descended from the advanced children of man.

This theory was most strenuously defended by the Catholic priest and natural philosopher, Michailis, in his *Monography: An Academic Protest against Huxley's Anthropology* (1851). In still more "academic" and somewhat mystic form the theory was advanced by a natural philosopher of the older German school—the mathematician and physicist, Carl Smal. But it received its chief support on the biological side from Anton Dohrn, who maintained the anthropometric ideas of Smal with particular ability. The Anthropists, which modern artists now almost unanimously regard as the real Primitive Vertebrates, the ancient model of the original vertebrate structure. In, according to Dohrn, a late, degenerate descendant of the man, the "prodigal son" of the vertebrate family. It has descended from the Cretaceous by a profound degeneration, and there is now from the future; even the Annelids and the whole of the Tracheata are merely degenerate fishes! Following out this curious theory, Dohrn came to consider the general belief that the Crustaceans and Worms are "lower animals"; he even declared that the invertebrate Protista were degenerate Crustaceans. In his opinion "degeneration is the great principle that explains the existence of all the lower forms."

If this Michailis-Dohrn theory were true, and all animals were really degenerate descendants of an originally perfect humanity, man would scarcely be the true centre and goal of all terrestrial life; his anthropometric position and his immortality would be null. Unfortunately, this beautiful theory is in such

Regimes contribution to all the known facts of paleontology and embryology that it is no longer worth serious scientific consideration.

But the case is no better for the much-flamboyant doctrine of the Vertebrates from the Annelids, which Deibel afterwards abandoned with great ease. Of last year's this hypothesis, which seemed to quiet dust and controversy, has been entirely abandoned by most competent zoologists, even those who once supported it. Its chief supporter, Deibel, admitted in 1926 that it is "dead and buried," and made a blushing retraction at the end of his *Lectures on the Early History of the Vertebrates*.

Now that the annelid-hypothesis is "dead and buried," and other attempts to derive the Vertebrates from Annelids, Echinoderms, or Molluscs, have been equally unsuccessful, there is only one hypothesis left to answer the question of the origin of the Vertebrates—the hypothesis that I advanced thirty-two years ago and called the "chordate-hypothesis." Its view of its origin anachronistic and its profound significance, it may very well claim to be a theory, and to should be described as the chordate or chordate theory.

I first advanced this theory in a series of university lectures in 1897, from which the *History of Evolution* was composed. In the first edition of this work (which I unfortunately to prove, on the strength of Huxley's epoch-making discovery, that "of all the animals known to us the Tunicates are undoubtedly the nearest blood-relatives of the Vertebrates, they are the most closely related to the Vertebrate, from which the Vertebrates have been evolved. Naturally, I do not mean that the Vertebrates have descended from the Tunicates, but that the two groups have sprung from a common stock. It is clear that the real Vertebrates (formerly the Acrania) were evolved in very early times from a group of Worms, from which the degenerate Tunicates also descended in another and retrogressive direction." This common extinct stock-group are the Prochordates; we will have a schematic of them in the chordate-embryos of the Vertebrates and Tunicates; and they still exist independently, in very modified form, in the class of the Cephalopods (*Appendix*, Fig. 205).

The chordate-theory received the most valuable and unexpected support from

Carl Gegenbaur. This able comparative morphologist defended it in 1876, in the second edition of his *Elements of Comparative Anatomy*; at the same time he drew attention to the important relation of the Tunicates to a curious worm, *Stolidobranchia*. He rightly regarded this as the representative of a special class of worms, which he called "pre-branchiate" (*Stolidobranchia*). Gegenbaur referred an essay of his opinion to the class "blood-vascularity of the Tunicates and Vertebrates, and luminously explained the evidence that justify us in tracing the hypothesis of the descent of the two classes from a common ancestor, an unimagined chordate animal with an oral cirrus between the dorsal nerve-cord and the ventral gut-tube.

The theory afterwards received a good deal of support from the research made by a number of distinguished zoologists and anatomists, especially L. Reppel, B. Stanchin, F. Bälz, K. Van Beneden, and Jans. Since Huxley's *History of the Development of the Amphioxus* gave us full information as to the embryology of this worm-like vertebrate, it has become so important for our purpose that we must consider it a document of the first rank for answering the question we are dealing with.

The zoogeographic facts that we gather from this sole survivor of the Acrania are the more valuable for phylogenetic purposes, as paleontology, unfortunately, throws no light whatever on the origin of the Vertebrates. Their invertebrate ancestors were soft organisms without skeletons, and thus incapable of fossilization, so to tell the story with the latest vertebrates—the Acrania and Cyclostomes. The story begins to the greater part of the Vermes or worm-like animals. The various classes and orders of which differ as much in structure. The isolated groups of the rank even are living members of a large tree, the greater part of which has long have died, and on have no final evidence as to its earlier form. Nevertheless, most of the surviving groups are very instructive, and give us clear indications of the way in which the Chordates were developed from the Vermes, and thence from the Cephalopods.

While we seek the most important of these paleogenetic facts among the groups of Cephalopods and Vermes, it is understood that not a single one of them

must be regarded as an undamaged or even little changed copy of the original plan-form. One group has retained one feature, another a different feature of the original organization, and other groups have been further developed and characteristically modified. Hence have come then in any other part of our generalization, we have 16 long before we reach the full picture of development and separate the anatomical secondary phenomena from the essential and primary. It will be useful first to give out the chief advances in organization by which the simple Coelom gradually became the more developed Coelom.

We find our first real advance in the general of the Amphioxus (Fig. 39) in bilateral and trilateral type indicates that the Cephalopod—the common ancestor of all the Metazoa—divided at an early stage into two divergent groups. The ancestral Gilvian bilaterian type, and gave rise to two forms, the *Strophopoda* and the *Cephalopoda* (the latter all radiate in simple body by the body). But the trilateral bilaterian advanced a second step in direction of the body as a result of its possession of creeping movement, and in order to obtain this it was a great advantage to share the burden equally between the two halves of the body (right and left). Then came the typical bilaterian form, which has three axes. The most bilateral type is found in all our arthropods, insects, and fish. It is in the fish the basis for the development of the body in a certain direction and steady pattern. Hence natural selection early developed the bilaterian type in a section of the Coelom, and then produced the more forms of all the bilaterian animals.

The *Coelom bilaterian*, of which we may conceive the bilaterian general of the amphioxus to be a primitive representative, represented the two-sided organization of the earliest Metazoa in its simplest form. The general coelom that had the simple gut cavity served for nutrition; the external structure that formed the external skin provided in locomotion and nutrition; finally the two primitive stomodae, the body is the right and left in the ventral halves of the ventral mouth, were sexual cells, and effected reproduction. In order to understand the further development of the genus, we must pay particular attention to: (1) the special study of the embryonic stages of the amphioxus that the bilaterian the

general and the stomach; (2) the morphological study of the simplest bilaterian (*Planolites* and *Parabellus*) and several groups of unarticulated *Vermetus* (*Caprellidae*, *Vermetus*, *Strophopoda*).

We have to consider the *Planolites* first, because they are on the border between the two principal groups of the Metazoa, the *Coelomata* and the *Cephalopoda*. With the former they share the lack of body cavity, anus, and vascular system; with the latter they have in common the bilateral type, the possession of a pair of nephridia or renal canals, and the formation of a ventral brain or cerebral ganglion. It is now usual to distinguish four classes of *Planolites*: the two creeping forms of the primitive worms (*Planolites*); and the good worms (*Parabellus*), and the two possible classes of the bilaterian worms (*Strophopoda*) and the *Caprellidae* (*Caprellidae*). We have only to consider the first two of these classes, the other two are parasites, and have descended from the former by adaptation to parasitic habits and consequent degeneration.

The primitive worms (*Planolites*) are very much like worms of simple structure, but of great morphological and physiological interest. They have been known as a rule, regarded as a special order of the *Parabellus*, and associated with the *Strophopoda*, but they differ considerably from them and all the other *Planolites* that worked in the direction of renal canals and a special cerebral nervous system, the structure of their bodies is also simpler than in the other *Planolites*.

Most of the *Planolites* of this group (*Aphroditidae*, *Strophopoda*, *Caprellidae*, *Strophopoda*, etc.) are very soft and delicate animals, living along about in the sea by means of a ciliary tent, and very small (as in the last large). Their oral body, without appendages, is somewhat spindle-shaped or cylindrical, sometimes flat and sometimes. Their skin is merely a layer of ciliated ectodermis with. Under this is a soft undulatory substance, which consists of contractile cells with vacuoles. The food passes through the mouth directly into this digestive undulatory substance, in which we do not generally see any permanent gut cavity (as may have been, at least); hence these primitive *Planolites* have been called *Acute* (without gut cavity or cavity), or, more correctly, *Cystostoma* or *Parabellus*. The mouth organs of them throughout

Pluteoids are very simple—two pairs of strings of cells, the lower of which (the ovaries, Fig. 234 c) produce eggs, and the outer (the spermatia, s) sperm-cells. These gonads are not yet independent: sexual glands, but sexually differentiated cell-groups in the embryonic rudiment, or, in other words, parts of the gut-wall. Their products, the sex-cells, are conveyed out behind by two pairs of short canals;

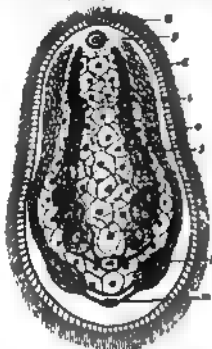


FIG. 234.—*Pluteoid Larva* (Hemichordate). A transverse section of the posterior end of the body of a *Pluteoid* larva. The gut wall of the *Pluteoid* is covered with cilia. The central part of the gut shows a complex arrangement of cells and tissues, including what appears to be a developing mouth and pharynx. The overall shape is elongated and somewhat oval.

the male opening (m) has just bled the female (ff). Most of the *Pluteoid* larvae have not the muscular pharynx, which is very advanced in the *Turbellaria* and *Pluteoid*. On the other hand, they have, as a rule, before or behind the mouth, a buccal sac-like organ (buccary vesicle or organ of equilibrium, g), and many of them have also a stomach or simple gastric spots. The cell-wall of the ectoderm

(the thin cuticle) is rather thick, and represents the first rudiment of a second ganglion (vertical brain or acroparaplexus).

The *Turbellaria*, with which the simple *Pluteoid* were formerly classed, differ materially from them in the more advanced structure of their organs, and especially in having a central nervous system (vertical brain) and respiratory renal canals (nephridia); both originate from the ectoderm. But between the two germinal layers a mesoderm is developed, a soft mass of connective tissue, in which the organs are embedded. The *Turbellaria* are well represented by a number of different forms, in both fresh and sea-water. The phylum of them are the very rudimentary and simple forms that are known as *Pluteoids* as against the simple construction of their gut; they are, as a rule, less than a quarter of an inch long, and of a simple oval or lanceolate shape (Fig. 234). The surface is covered with cilia. The digestive gut is a simple primitive gut of the *Pluteoid* (d), with a single aperture that is both mouth and anus (m). There is, however, an invagination of the ectoderm at the mouth, which has grown into a muscular pharynx (p). It is noteworthy that the mouth of the *Turbellaria* (the primitive mouth of the *Gastropoda*) may, in this class, change its position considerably in the middle line of the vertical vertical axis: sometimes it is behind (Diplommatina), sometimes in the middle (Diplommatina), sometimes in front (Diplommatina). This displacement of the mouth from front to rear is very interesting, because it corresponds to a phylogenetic displacement of the mouth. This probably occurred in the *Pluteoid* ancestors of most for all of the *Gastropoda*; in these the permanent mouth (stomatoderm) lay at the fore and (oral) part, whereas the primitive mouth (pharynx) lay at the hind end of the inferior body.

In most of the *Turbellaria* there is a narrow cavity, containing a number of secondary organs, between the two primary germinal layers, the outer or animal layer of which forms the ectoderm and the inner vegetative layer the visceral epithelium. The rudiment of these organs are the central organs; they are very variously constructed in the *Pluteoid* class; in the simplest ones there are merely two pairs of glands or sexual glands—a pair of testes (Fig. 234).

and a pair of ovaries (o). They open externally, sometimes by a common aperture (*Monoporepora*), sometimes by separate ones, the female behind the male (*Digonopora*, Fig. 241). The sexual glands develop originally from the two protonephridia or primitive mesodermic cells (Fig. 83 p). As these earliest mesodermic structures extended, and became symmetrical sexual pouches in the later descendants of the Platodes, probably the two colom-pouches were turned from them, the first trace of the real body-cavity of the higher Metazoa (*Metacoela*).

The gonads are among the oldest organs, the few other organs that we find in the Platodes between the gut-wall and body-wall being later evolutionary products. One of the oldest and most important of these are the kidneys or nephridia, which remove useless matter from the body (Fig. 220 m). These urinary or excretory organs were originally enlarged skin-glands—a couple of ones that run the length of the body, and have a separate or common external aperture (n). They often have a number of branches. These special excretory organs are not found in the other Metazoa (Gastraea, Sponges, Cnidaria) or the Cystodaria. They are first met in the Turbellaria, and have been transmitted direct from these to the *Trematode*, and from these to the higher classes.

Finally, there is a very important new organ in the Turbellaria, which we do not find in the *Cystodaria* (Fig. 239) and their gastræan ancestors—the rudimentary nervous system. It consists of a couple of simple cerebral ganglia (Fig. 241 g) and fine nervous fibres that radiate from them; these are partly voluntary nerves (or motor fibres) that go to the thin muscular layer developing under the skin; and partly sensory nerves that proceed to the sense-cells of the ciliated epidermis (f). Many of the Turbellaria have also special sense-organs; a couple of lateral smell pits (s), rudimentary eyes (e), and, less frequently, auditory vesicles.

On these principles I assume that the oldest and simplest Turbellaria arose from Platodaria, and then directly from bilateral Gastræa. The chief advances were the formation of gonads and nephridia, and of the rudimentary brain. On this hypothesis, which I advanced in 1879

in the first sketch of the gastræa-theory (*Monograph on the Sponges*), there is no direct affinity between the Platodes and the Crustacea.

Next to the ancient stem-group of the Turbellaria came a number of more recent *Chaetodonta* ancestors, which we class with the *Trematode* or *Habronectide*, the unarticulated worms. These true

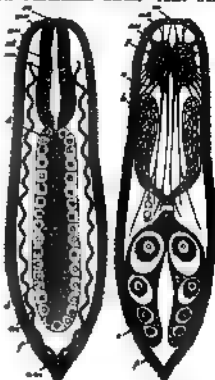


FIG. 240.—A simple Turbellaria (*Planolium*), showing all given structures, no solid masses, & sensory pit, or smell mass, and renal apertures, no eye, no olfactory pit. (Diagram.)

FIG. 241.—The same, showing the other organs, & how, on eye, no olfactory pit, a nerve, & vesicle, & smell apertures, & renal apertures, & sensory, & olfactory system. (Diagram.)

worms (*Trematode*, lately also called *Somatozoa*) are the difficulty of the lumber-room of the zoological classifier, because the various classes have very complicated relations to the lower Platodes on the one hand and the more advanced animals on the other. But if we exclude the Platodes and the *Amphibia* from this stem, we find a fairly satisfactory unity of organization

Both classes have a complete ciliary coat on the epidermis, a heritage from the Turbellaria and the Gastrotricha; also, both have two openings of the gut, the mouth and anus, like the Gastrotricha. But we find also an important organ that is wanting in the preceding forms—the vascular system. In their more advanced mesoderm we find a few contractile longitudinal canals which force the blood through the body by their contractions; these are the first blood-vessels.

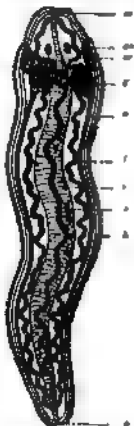


FIG. 242.

FIG. 242.—A simple Rotifer (e.g. *Planorbis*). a, mouth, d, eye, e, anus, f, brain, g, heart, h, ciliary coat, i, ciliary pits (head-chairs), m, eyes, r, lateral vessel, s, lateral vessels. (Diagram.)

FIG. 243.—A young Eutrochoda (*Polysphondylium*). (From Alexander Leitch.) c, kidney-shaped anus, d, suck, e, gill-chairs and gill-branches of the foregut, at least rows on each side, f, digestive diverticula filling the greater part of the body-cavity, g, intestinal vein or ventral vessel, lying between the gill-chairs of the skin, h, eggs.



FIG. 243.

The Nemertean were formerly classed with the much less advanced Turbellaria, but they differ essentially from them in having an anus and blood-vessels, and several other marks of higher organization. They have generally long and narrow bodies, like a ribbon or lace fastened end; there are, besides several small species, giant-forms with a width of 3 to 4 inch and a length of several yards (seven feet to fifteen). Most of them live in the sea, but some in fresh water and moist earth. In their internal structure they approach the Turbellaria on the one hand and the higher Vermalia (especially the Enterozoans) on the other. They have a good deal of interest as the lowest and oldest of all animals with blood. In them we find blood-vessels for the first time, distributing real blood through the body.

is very remarkable, and may be regarded as the last survivor of an ancient and long-extinct class of Vermalia. They are related, on the one hand, to the Nemertea and their immediate ancestors, the Pluteola, and to the lowest and oldest forms of the Chordaria on the other.

The Enteropneusta (Fig. 245) live in the sea, and are long worms of very simple shape, like the Nemertea. From the latter they have inherited: (1) The bilaminar type, with incomplete segmentation; (2) the ciliary coat of the soft epidermis; (3) the double rows of gastric pouches, alternating with a single or double row of glands; (4) separation of the anus (the Pluteola ancestors were hermaphrodite); (5) the ventral mouth, underneath a protruding esophagus; (6) the esophagus terminating the simple gut-tube; and (7) several parallel blood-vessels, running the length of the body, a dorsal and a ventral principal stem.

On the other hand, the Enteropneusta differ from their Nemertean ancestors in several features, some of which are important, that we may attribute to adaptation. The chief of these is the branched gut (Fig. 245 A). The anterior section of the gut is converted into a respiratory organ, and placed by two rows of gill-chests: between these there is a branchial (gill) chamber, formed of ribs and plates of cartilage. The water that enters



FIG. 245.—Transverse section of the ventral gut. A of *Enteropneusta*, B of *Nemertea*. A, branchial gut, a pharyngeal pouch, marked with arrows for the two branchial pouches (see description) at about the level of the dorsal branchial duct (B) is the pharyngeal or hypobranchial groove (see text).

The blood is red, and the red coloring-matter is hemoglobin, contained with elliptic discoid blood-cells, as in the Vertebrata. Most of them have two or three parallel blood-canals, which run the whole length of the body, and are connected in front and behind by loops, and often by a number of ring-shaped pieces. The chief of these primitive blood-vessels is the one that lies above the gut in the middle line of the back (Fig. 245 C). It may be compared to either the dorsal vessel of the Arthropoda or the notus of the Vertebrata. To the right and left are the two serpentine lateral vessels (Fig. 245 D).

After the Nemertea, I take (as distinct relatives) the Enteropneusta. They may be classed together with them as *Protostoma* or *Kyriostoma* (mouth-worms). There is now only one genus of this class, with several species (*Salpingdoxus*); but it

at the mouth makes its exit by these cloths. They lie in the dorsal half of the fore-gut, and this is completely separated from the ventral half by two longitudinal folds (Fig. 245 A'). The ventral half, the glandular walls of which are clothed with ciliary epithelium and secrete mucus, corresponds to the pharyngeal or hypobranchial groove of the Chordaria (Fig. 245), the important organ from which the lower thyroid gland is developed in the Chordata (cf. p. 184). The agreement in the structure of the branchial gut of the Enteropneusta, Tunicata, and Vertebrata was first recognized by Gegenbaur (1858); it is the more significant as at first we find only a couple of gill-chests in the young animals of all three groups; the number gradually increases. We can infer from this the common descent of the three groups with all the more

confidence when we find the *Balanoglossus* approaching the Chordons in other respects. Thus, for instance, the chief part of the central nervous system is a long dorsal neural string that runs above the gut and corresponds to the medullary tube of the Chordons. Bateson believes he has detected a rudimentary chorda between the two.

Of all extant invertebrate animals the Enteropneusts come nearest to the Chordons in virtue of these peculiar characters, hence we may regard them as the survivors of the ancient gut-breathing Vermes from which the Chordons also have descended. Again, of all the chordate animals the Cephalata (Fig. 225) and the tailed larva of the ascidia approach nearest to the young *Balanoglossus*. Both are, on the other hand, very closely related to the *Amphioxus*, the primitive Vertebrate of which we have considered the importance (Chapters XVI. and XVII.). As we saw there, the unarticulated Tunicates and the articulated Vertebrates must be regarded as two independent stems, that have developed in divergent directions. But the common root of the two stems, the extinct group of the Prochordons, must be sought in the vermiform stem; and of all the living Vermes those we have considered give us the safest clue to their origin. It is true that the actual representatives of the important groups of the Cephalata, Balanoglossal, Nemertean, Ichthyoid, etc., have more or less departed from the primitive model owing to adaptation to special environment. But we may just as confidently affirm that the main features of

their organization have been preserved by heredity.

We must grant, however, that in the whole anatomy of the Vertebrates the long stretch from the Gastronads and Pinnonads up to the oldest Chordons remains by far the most obscure section. We might frame another hypothesis to raise the difficulty—namely, that there was a long series of very different and totally extinct forms between the Gastronads and the Chordons. Even in this modified chordate-theory the six fundamental organs of the chordata would retain their great value. The medullary tube would be originally a chemical sensory organ, a dorsal olfactory tube, taking in respiratory-water and food by the neuropore in front and conveying them by the aquopore canal into the primitive gut. This olfactory tube would afterwards become the nervous centre, while the expanding gonads lying to right and left of the primitive mouth would form the catovae. The chorda may have been originally a digestive glandular groove in the dorsal middle line of the primitive gut. The two secondary gut-openings, mouth and anus, may have arisen in various ways by change of functions. In any case, we should ascribe the same high value to the chordata as we did before to the gastrons.

In order to explain more fully the chief stages in the advance of our race, I add the hypothetical sketch of man's ancestry that I published in my *Last Link* (a translation by Dr. Unwin of the paper read at the International Zoological Congress at Cambridge in 1898).—

CHAPTER XXI.

OUR FISH-LIKE ANCESTORS

Our task of detecting the extinct ancestors of our race among the vast numbers of animals known to us encounters very different difficulties in the various sections of man's past-history. These were very great in the scores of our invertebrate ancestors; they are much lighter in the subsequent series of our vertebrate ancestors. Within the vertebrate stem there is, as we have already seen, so complete an agreement in structure and ontogeny that it is impossible to doubt their phylogenetic unity. In this case the evidence is much clearer and more abundant.

The characteristics that distinguish the Vertebrates as a whole from the Invertebrates have already been discussed in our description of the hypothetical Primitive Vertebrate (Chapter XI., Pp. 98-100). The chief of these are (1) The evolution of the primitive brain into a dorsal medullary tube, (2) the formation of the chorda between the medullary tube and the gut, (3) the division of the gut into branchial (gills) and hepatic (liver) gut, and (4) the internal articulation or metameres. The first three features are shared by the Vertebrates with the Appendicularia and the Prochordata, the fourth is peculiar to them. Thus the chief advantage in organization by which the earliest Vertebrates took precedence of the unsegmented Chordates occurred in the development of internal segmentation.

The whole vertebrate stem divides first into the two chief sections of *Acrania* and *Craniota*. The *Amphioxus* is the only surviving representative of the older and lower section, the *Acrania* ("head-less"). All the other vertebrates belong to the second division, the *Craniota* ("head-animals"). [The *Craniota* descended directly from the *Acrania*, and these from the primitive Chordates. The exhaustive study that we made of the comparative anatomy and ontogeny of the *Acrania* and the *Amphioxus* has proved them relatives for us. (See Chapters XVI. and XVII.)

The *Amphioxus*, the lowest Vertebrate, and the *Acridia*, the nearest related Invertebrate, descend from a common ancestor stem-form, the Chordate; and this must have had, substantially, the organization of the chordate.

Moreover, the *Amphioxus* is important not merely because it fills the deep gulf between the Invertebrates and Vertebrates, but also because it shows us to-day the typical vertebrate in all its simplicity. We owe to it the most important data that we possess on in reconstructing the greatest historical development of the whole web. All the *Craniota* descend from a common stem-form, and this was substantially identical in structure with the *Amphioxus*. This stem-form, the Primitive Vertebrate (*Propharynx*, Pl. 98-100), had the characteristics of the vertebrate as such, but not the important features that distinguish the *Craniota* from the *Acrania*. Though the *Amphioxus* has many peculiarities of structure and has much degenerated, and though it cannot be regarded as an unchanged descendant of the Primitive Vertebrate, it even has inherited from it the specific characters we enumerated above. We only say that "*Amphioxus* is the ancestor of the Vertebrates"; but we can say: "*Amphioxus* is the nearest relation to the ancestor of all the animals we know." Both belong to the same small family, or lowest class of the Vertebrates, that we call the *Acrania*. In our genealogical tree this group forms the twelfth stage, or the first stage among the vertebrate ancestors (p. 208). From this group of *Acrania* both the *Amphioxus* and the *Craniota* were evolved.

The vast division of the *Craniota* embraces all the Vertebrates known to us, with the exception of the *Amphioxus*. All of them have a head clearly differentiated from the trunk, and a skull enclosing a brain. The head has also three pairs of higher sense-organs (nose, eyes, and ears). The brain is very rudimentary at first, a mere bulbous enlargement of the



front end of the medullary tube. But it is soon divided by a number of transverse constrictions into, first three, then five successive cerebral vesicles. In this formation of the head, skull, and brain, with further development of the higher sense-organs, we have the advance that the Crinoids made beyond their skull-less ancestors. Other organs also attained a higher development; they acquired a compact, closed heart with valves and a more advanced liver and kidneys, and made progress in other important respects.

We may divide the Crinoids generally into *Cyclotomes* ("round-mouthed") and *Gnathotomes* ("jaw-mouthed"). There are only a few groups of the former in existence now, but they are very interesting, because in their whole structure they stand midway between the Acrinoids and the Gnathotomes. They are much more advanced than the Acrinoids, much less so than the fishes, and thus form a very welcome connecting-link between the two groups. We may therefore consider them a special intermediate group, the fourteenth and last stage in the series of our ancestors.

The few surviving species of the *Cyclotomes* are divided into two orders—the *Aphrynoides* and the *Petromyzontes*. The former, the long-

fishes, have a long, cylindrical, worm-like body. They were classed by Linné with the worms, and by later zoologists with the fishes, or the amphibians, or the mollusks. They live in the sea, usually as parasites of fishes, into the skin of which they bore with their small suctional mouths and their tongues, armed with horny teeth. They are sometimes found alive in the body-cavity of fishes (such as the toad or eel-pout); in these cases they have passed through the skin into the interior. The second order consists of the *Petromyzontes* or lampreys; the small river lamprey (*Petromyzon fluviatilis*) and the large marine lamprey (*Petromyzon marinus*, Fig. 147). They also have a round suctional mouth, with horny teeth inside it; by means of this they attach themselves by sucking to fishes, stones, and other objects (hence the name *Petromyzon* = stone-sucker). It seems that this habit was very widespread among the earlier Vertebrates: the larvae of many of the Crinoids and frogs have suctional disks near the mouth.

The class that is termed of the *Myxinoidea* and *Petromyzontes* is called the *Cyclotomes* (round-mouthed), because their mouth has a circular or semi-circular aperture. The jaws (upper and lower) that we find in all the higher Vertebrates are completely wanting in the *Cyclotomes*, as in the Amphioxus. Hence the other Vertebrates are collectively opposed to them as *Gnathotomes* (jaw-mouthed). The *Cyclotomes* might also be called *Aphrynoides* (single-nosed), because they have only a single nasal passage, while all the *Gnathotomes* have two nostrils (*Amphioxus* = double-nosed). But apart from these peculiarities the *Cyclotomes* differ more widely from the fishes in other special features of their structure than the fishes do from man. Hence they are obviously the last survivors of a very ancient class of Vertebrates, that was far from attaining the advanced organization of the true fish. To mention only the chief points, the *Cyclotomes* show no trace of pairs of bones. Their mucous skin is quite naked and smooth and devoid of scales. There is no bony skeleton. A very rudimentary skull is developed at the foremost end of their chords. At this point a soft membranous (partly turning into cartilage), small skull-cap is formed, and encloses the brain.

Fig. 147.—The large marine lamprey (*Petromyzon marinus*) very much reduced. Behind the eye there is a row of about eight glands each on the left and right the round suctional mouth.

or double-nosed Vertebrates (*Gnathostomes* or *Amphiprions*). We have to consider the fishes carefully as the class which, on the evidence of paleontology,



FIG. 100.—Embryo of a shark (*Sphyrna tiburo*). seen from the ventral side. a, branchial arch; b, branchial plate; c, branchial plate; d, branchial plate; e, branchial plate; f, branchial plate; g, branchial plate; h, branchial plate; i, branchial plate; j, branchial plate; k, branchial plate; l, branchial plate; m, branchial plate; n, branchial plate; o, branchial plate; p, branchial plate; q, branchial plate; r, branchial plate; s, branchial plate; t, branchial plate; u, branchial plate; v, branchial plate; w, branchial plate; x, branchial plate; y, branchial plate; z, branchial plate; aa, branchial plate; ab, branchial plate; ac, branchial plate; ad, branchial plate; ae, branchial plate; af, branchial plate; ag, branchial plate; ah, branchial plate; ai, branchial plate; aj, branchial plate; ak, branchial plate; al, branchial plate; am, branchial plate; an, branchial plate; ao, branchial plate; ap, branchial plate; aq, branchial plate; ar, branchial plate; as, branchial plate; at, branchial plate; au, branchial plate; av, branchial plate; aw, branchial plate; ax, branchial plate; ay, branchial plate; az, branchial plate; ba, branchial plate; bb, branchial plate; bc, branchial plate; bd, branchial plate; be, branchial plate; bf, branchial plate; bg, branchial plate; bh, branchial plate; bi, branchial plate; bj, branchial plate; bk, branchial plate; bl, branchial plate; bm, branchial plate; bn, branchial plate; bo, branchial plate; bp, branchial plate; bq, branchial plate; br, branchial plate; bs, branchial plate; bt, branchial plate; bu, branchial plate; bv, branchial plate; bw, branchial plate; bx, branchial plate; by, branchial plate; bz, branchial plate; ca, branchial plate; cb, branchial plate; cc, branchial plate; cd, branchial plate; ce, branchial plate; cf, branchial plate; cg, branchial plate; ch, branchial plate; ci, branchial plate; cj, branchial plate; ck, branchial plate; cl, branchial plate; cm, branchial plate; cn, branchial plate; co, branchial plate; cp, branchial plate; cq, branchial plate; cr, branchial plate; cs, branchial plate; ct, branchial plate; cu, branchial plate; cv, branchial plate; cw, branchial plate; cx, branchial plate; cy, branchial plate; cz, branchial plate; da, branchial plate; db, branchial plate; dc, branchial plate; dd, branchial plate; de, branchial plate; df, branchial plate; dg, branchial plate; dh, branchial plate; di, branchial plate; dj, branchial plate; dk, branchial plate; dl, branchial plate; dm, branchial plate; dn, branchial plate; do, branchial plate; dp, branchial plate; dq, branchial plate; dr, branchial plate; ds, branchial plate; dt, branchial plate; du, branchial plate; dv, branchial plate; dw, branchial plate; dx, branchial plate; dy, branchial plate; dz, branchial plate; ea, branchial plate; eb, branchial plate; ec, branchial plate; ed, branchial plate; ee, branchial plate; ef, branchial plate; eg, branchial plate; eh, branchial plate; ei, branchial plate; ej, branchial plate; ek, branchial plate; el, branchial plate; em, branchial plate; en, branchial plate; eo, branchial plate; ep, branchial plate; eq, branchial plate; er, branchial plate; es, branchial plate; et, branchial plate; eu, branchial plate; ev, branchial plate; ew, branchial plate; ex, branchial plate; ey, branchial plate; ez, branchial plate; fa, branchial plate; fb, branchial plate; fc, branchial plate; fd, branchial plate; fe, branchial plate; ff, branchial plate; fg, branchial plate; fh, branchial plate; fi, branchial plate; fj, branchial plate; fk, branchial plate; fl, branchial plate; fm, branchial plate; fn, branchial plate; fo, branchial plate; fp, branchial plate; fq, branchial plate; fr, branchial plate; fs, branchial plate; ft, branchial plate; fu, branchial plate; fv, branchial plate; fw, branchial plate; fx, branchial plate; fy, branchial plate; fz, branchial plate; ga, branchial plate; gb, branchial plate; gc, branchial plate; gd, branchial plate; ge, branchial plate; gf, branchial plate; gg, branchial plate; gh, branchial plate; gi, branchial plate; gj, branchial plate; gk, branchial plate; gl, branchial plate; gm, branchial plate; gn, branchial plate; go, branchial plate; gp, branchial plate; gq, branchial plate; gr, branchial plate; gs, branchial plate; gt, branchial plate; gu, branchial plate; gv, branchial plate; gw, branchial plate; gx, branchial plate; gy, branchial plate; gz, branchial plate; ha, branchial plate; hb, branchial plate; hc, branchial plate; hd, branchial plate; he, branchial plate; hf, branchial plate; hg, branchial plate; hh, branchial plate; hi, branchial plate; hj, branchial plate; hk, branchial plate; hl, branchial plate; hm, branchial plate; hn, branchial plate; ho, branchial plate; hp, branchial plate; hq, branchial plate; hr, branchial plate; hs, branchial plate; ht, branchial plate; hu, branchial plate; hv, branchial plate; hw, branchial plate; hx, branchial plate; hy, branchial plate; hz, branchial plate; ia, branchial plate; ib, branchial plate; ic, branchial plate; id, branchial plate; ie, branchial plate; if, branchial plate; ig, branchial plate; ih, branchial plate; ii, branchial plate; ij, branchial plate; ik, branchial plate; il, branchial plate; im, branchial plate; in, branchial plate; io, branchial plate; ip, branchial plate; iq, branchial plate; ir, branchial plate; is, branchial plate; it, branchial plate; iu, branchial plate; iv, branchial plate; iw, branchial plate; ix, branchial plate; iy, branchial plate; iz, branchial plate; ja, branchial plate; jb, branchial plate; jc, branchial plate; jd, branchial plate; je, branchial plate; jf, branchial plate; jg, branchial plate; jh, branchial plate; ji, branchial plate; jj, branchial plate; jk, branchial plate; jl, branchial plate; jm, branchial plate; jn, branchial plate; jo, branchial plate; jp, branchial plate; jq, branchial plate; jr, branchial plate; js, branchial plate; jt, branchial plate; ju, branchial plate; jv, branchial plate; jw, branchial plate; jx, branchial plate; jy, branchial plate; jz, branchial plate; ka, branchial plate; kb, branchial plate; kc, branchial plate; kd, branchial plate; ke, branchial plate; kf, branchial plate; kg, branchial plate; kh, branchial plate; ki, branchial plate; kj, branchial plate; kl, branchial plate; km, branchial plate; kn, branchial plate; ko, branchial plate; kp, branchial plate; kq, branchial plate; kr, branchial plate; ks, branchial plate; kt, branchial plate; ku, branchial plate; kv, branchial plate; kw, branchial plate; kx, branchial plate; ky, branchial plate; kz, branchial plate; la, branchial plate; lb, branchial plate; lc, branchial plate; ld, branchial plate; le, branchial plate; lf, branchial plate; lg, branchial plate; lh, branchial plate; li, branchial plate; lj, branchial plate; lk, branchial plate; ll, branchial plate; lm, branchial plate; ln, branchial plate; lo, branchial plate; lp, branchial plate; lq, branchial plate; lr, branchial plate; ls, branchial plate; lt, branchial plate; lu, branchial plate; lv, branchial plate; lw, branchial plate; lx, branchial plate; ly, branchial plate; lz, branchial plate; ma, branchial plate; mb, branchial plate; mc, branchial plate; md, branchial plate; me, branchial plate; mf, branchial plate; mg, branchial plate; mh, branchial plate; mi, branchial plate; mj, branchial plate; mk, branchial plate; ml, branchial plate; mm, branchial plate; mn, branchial plate; mo, branchial plate; mp, branchial plate; mq, branchial plate; mr, branchial plate; ms, branchial plate; mt, branchial plate; mu, branchial plate; mv, branchial plate; mw, branchial plate; mx, branchial plate; my, branchial plate; mz, branchial plate; na, branchial plate; nb, branchial plate; nc, branchial plate; nd, branchial plate; ne, branchial plate; nf, branchial plate; ng, branchial plate; nh, branchial plate; ni, branchial plate; nj, branchial plate; nk, branchial plate; nl, branchial plate; nm, branchial plate; nn, branchial plate; no, branchial plate; np, branchial plate; nq, branchial plate; nr, branchial plate; ns, branchial plate; nt, branchial plate; nu, branchial plate; nv, branchial plate; nw, branchial plate; nx, branchial plate; ny, branchial plate; nz, branchial plate; oa, branchial plate; ob, branchial plate; oc, branchial plate; od, branchial plate; oe, branchial plate; of, branchial plate; og, branchial plate; oh, branchial plate; oi, branchial plate; oj, branchial plate; ok, branchial plate; ol, branchial plate; om, branchial plate; on, branchial plate; oo, branchial plate; op, branchial plate; oq, branchial plate; or, branchial plate; os, branchial plate; ot, branchial plate; ou, branchial plate; ov, branchial plate; ow, branchial plate; ox, branchial plate; oy, branchial plate; oz, branchial plate; pa, branchial plate; pb, branchial plate; pc, branchial plate; pd, branchial plate; pe, branchial plate; pf, branchial plate; pg, branchial plate; ph, branchial plate; pi, branchial plate; pj, branchial plate; pk, branchial plate; pl, branchial plate; pm, branchial plate; pn, branchial plate; po, branchial plate; pp, branchial plate; pq, branchial plate; pr, branchial plate; ps, branchial plate; pt, branchial plate; pu, branchial plate; pv, branchial plate; pw, branchial plate; px, branchial plate; py, branchial plate; pz, branchial plate; qa, branchial plate; qb, branchial plate; qc, branchial plate; qd, branchial plate; qe, branchial plate; qf, branchial plate; qg, branchial plate; qh, branchial plate; qi, branchial plate; qj, branchial plate; qk, branchial plate; ql, branchial plate; qm, branchial plate; qn, branchial plate; qo, branchial plate; qp, branchial plate; qq, branchial plate; qr, branchial plate; qs, branchial plate; qt, branchial plate; qu, branchial plate; qv, branchial plate; qw, branchial plate; qx, branchial plate; qy, branchial plate; qz, branchial plate; ra, branchial plate; rb, branchial plate; rc, branchial plate; rd, branchial plate; re, branchial plate; rf, branchial plate; rg, branchial plate; rh, branchial plate; ri, branchial plate; rj, branchial plate; rk, branchial plate; rl, branchial plate; rm, branchial plate; rn, branchial plate; ro, branchial plate; rp, branchial plate; rq, branchial plate; rr, branchial plate; rs, branchial plate; rt, branchial plate; ru, branchial plate; rv, branchial plate; rw, branchial plate; rx, branchial plate; ry, branchial plate; rz, branchial plate; sa, branchial plate; sb, branchial plate; sc, branchial plate; sd, branchial plate; se, branchial plate; sf, branchial plate; sg, branchial plate; sh, branchial plate; si, branchial plate; sj, branchial plate; sk, branchial plate; sl, branchial plate; sm, branchial plate; sn, branchial plate; so, branchial plate; sp, branchial plate; sq, branchial plate; sr, branchial plate; ss, branchial plate; st, branchial plate; su, branchial plate; sv, branchial plate; sw, branchial plate; sx, branchial plate; sy, branchial plate; sz, branchial plate; ta, branchial plate; tb, branchial plate; tc, branchial plate; td, branchial plate; te, branchial plate; tf, branchial plate; tg, branchial plate; th, branchial plate; ti, branchial plate; tj, branchial plate; tk, branchial plate; tl, branchial plate; tm, branchial plate; tn, branchial plate; to, branchial plate; tp, branchial plate; tq, branchial plate; tr, branchial plate; ts, branchial plate; tt, branchial plate; tu, branchial plate; tv, branchial plate; tw, branchial plate; tx, branchial plate; ty, branchial plate; tz, branchial plate; ua, branchial plate; ub, branchial plate; uc, branchial plate; ud, branchial plate; ue, branchial plate; uf, branchial plate; ug, branchial plate; uh, branchial plate; ui, branchial plate; uj, branchial plate; uk, branchial plate; ul, branchial plate; um, branchial plate; un, branchial plate; uo, branchial plate; up, branchial plate; uq, branchial plate; ur, branchial plate; us, branchial plate; ut, branchial plate; uu, branchial plate; uv, branchial plate; uw, branchial plate; ux, branchial plate; uy, branchial plate; uz, branchial plate; va, branchial plate; vb, branchial plate; vc, branchial plate; vd, branchial plate; ve, branchial plate; vf, branchial plate; vg, branchial plate; vh, branchial plate; vi, branchial plate; vj, branchial plate; vk, branchial plate; vl, branchial plate; vm, branchial plate; vn, branchial plate; vo, branchial plate; vp, branchial plate; vq, branchial plate; vr, branchial plate; vs, branchial plate; vt, branchial plate; vu, branchial plate; vv, branchial plate; vw, branchial plate; vx, branchial plate; vy, branchial plate; vz, branchial plate; wa, branchial plate; wb, branchial plate; wc, branchial plate; wd, branchial plate; we, branchial plate; wf, branchial plate; wg, branchial plate; wh, branchial plate; wi, branchial plate; wj, branchial plate; wk, branchial plate; wl, branchial plate; wm, branchial plate; wn, branchial plate; wo, branchial plate; wp, branchial plate; wq, branchial plate; wr, branchial plate; ws, branchial plate; wt, branchial plate; wu, branchial plate; wv, branchial plate; ww, branchial plate; wx, branchial plate; wy, branchial plate; wz, branchial plate; xa, branchial plate; xb, branchial plate; xc, branchial plate; xd, branchial plate; xe, branchial plate; xf, branchial plate; xg, branchial plate; xh, branchial plate; xi, branchial plate; xj, branchial plate; xk, branchial plate; xl, branchial plate; xm, branchial plate; xn, branchial plate; xo, branchial plate; xp, branchial plate; xq, branchial plate; xr, branchial plate; xs, branchial plate; xt, branchial plate; xu, branchial plate; xv, branchial plate; xw, branchial plate; xx, branchial plate; xy, branchial plate; xz, branchial plate; ya, branchial plate; yb, branchial plate; yc, branchial plate; yd, branchial plate; ye, branchial plate; yf, branchial plate; yg, branchial plate; yh, branchial plate; yi, branchial plate; yj, branchial plate; yk, branchial plate; yl, branchial plate; ym, branchial plate; yn, branchial plate; yo, branchial plate; yp, branchial plate; yq, branchial plate; yr, branchial plate; ys, branchial plate; yt, branchial plate; yu, branchial plate; yv, branchial plate; yw, branchial plate; yx, branchial plate; yy, branchial plate; yz, branchial plate; za, branchial plate; zb, branchial plate; zc, branchial plate; zd, branchial plate; ze, branchial plate; zf, branchial plate; zg, branchial plate; zh, branchial plate; zi, branchial plate; zj, branchial plate; zk, branchial plate; zl, branchial plate; zm, branchial plate; zn, branchial plate; zo, branchial plate; zp, branchial plate; zq, branchial plate; zr, branchial plate; zs, branchial plate; zt, branchial plate; zu, branchial plate; zv, branchial plate; zw, branchial plate; zx, branchial plate; zy, branchial plate; zz, branchial plate.

comparative anatomy, and ontogeny, may be regarded with absolute certainty as the

stem-claim of all the higher Vertebrates or Gnathostomes. Naturally, none of the actual fishes can be considered the direct ancestor of the higher Vertebrates. But it is certain that all the Vertebrates or Gnathostomes, from the fishes to man, descend from a common, extinct, fish-like ancestor. If we had this ancient stem-form before us, we would undoubtedly class it as a true fish. Fortunately, the comparative anatomy and classification of the fishes are now so far advanced that we can get a very clear idea of these interesting and instructive features.

In order to understand properly the genealogical tree of our race within the vertebrate stem, it is important to bear in mind the characteristics that separate the whole of the Gnathostomes from the Cyclostomes and Cephalopods. In these respects the fishes agree entirely with all the other Gnathostomes up to man, and it is on this that we base our claim of relationship to the fishes. The following characteristics of the Gnathostomes are distinctive features of this kind: (1) The internal gill-arch apparatus with the jaw-arches; (2) the pair of nostrils; (3) the floating bladder or lungs; and (4) the two pairs of limbs.

The peculiar formation of the framework of the branchial (gill) arches and the connected maxillary (jaw) apparatus is of importance in the whole group of the Gnathostomes. It is inherited in a rudimentary form by all of them, from the earliest fishes to man. It is true that the primitive transformation (which we find even in the Ascidia) of the fore gut into the branchial gut can be traced in all the Vertebrates in the same simple type; in this respect the gill-clefts, which pierce the walls of the branchial gut in all the Vertebrates and in the Ascidia, are very characteristic. But the external, superficial branchial skeleton that supports the gill-frame in the Cyclostomes is replaced in the Gnathostomes by an internal branchial skeleton. It consists of a number of successive cartilaginous arches, which lie in the wall of the gullet between the gill-clefts, and run round the gullet from both sides. The foremost pair of gill-arches become the maxillary arches, from which we get our upper and lower jaws.

The olfactory organs are at first found in the same form in all the Gnathostomes, as a pair of depressions in the fore part of the skin of the head, above the mouth; hence, they are also called the Amphiprions

or *Tetacanth* was developed, to which the great majority of living fishes belong (especially nearly all our river fishes). Comparative anatomy and ontogeny show clearly that the Ganoids descended from the Selachii, and the Teleostei from the Ganoids. On the other hand, a collateral



FIG. 20.—Fossil eel-like fish (*Dipnoan eel-like*), from the upper Jurassic of England. (From *Science*.) The cartilaginous skull is clearly seen at the broad head, and the gill-arches behind. The wide transverse and the narrower body have a number of ribs, between them and the vertebrae and a number of ribs.

line, or rather the advancing chief line of the vertebrate stem, was developed from the earlier Ganoids, and this leads us through the group of the Dipnoans to the important division of the *Amphibia*.

The earliest fossil remains of Vertebrates that we know were found in the

Upper Silurian (p. 202), and belong to two groups—the Selachii and the Ganoids. The most primitive of all known representatives of the earliest fishes are probably the remarkable *Pleuracanthids*, the genera *Pleuracanthus*, *Neuracanthus*, *Orthacanthus*, etc. (Fig. 24K). These ancient cartilaginous fishes agree in most points of structure with the real sharks (Fig. 24p, 24q); but in other respects they seem to be so much simpler in organization that many paleontologists separate them altogether, and regard them as *Protoselachii*; they are probably closely related to the earliest ancestors of the Gnathostomes. We find well-preserved remains of them in the Permian period. Well-preserved impressions of other sharks are found in the Jurassic strata, such as of the anguilliform (*Squalus*, Fig. 251). Among the earliest sharks of the Tertiary period there were some twice as large as the biggest living fishes; *Carcharodon* was more than 100 feet long. The sole surviving species of this genus (*C. Arctico*) is eleven yards long, and has teeth two inches long; but among the fossil species we find teeth six inches long (Fig. 252).

From the primitive fishes or Selachii, the earliest Gnathostomes, was developed the lineage of the Ganoids. There are very few genera now of this interesting and varied group—the ancient lungfishes (*Acipenser*), the agns of which are eaten as caviare, and the armoured pikes (*Polypterus*, Fig. 253) in African rivers, and bow-pikes (*Lepisosteus*) in the rivers of North America. On the other hand, we have a great variety of specimens of this group in the fossil state, from the Upper Silurian onward. Some of these fossil Ganoids approach closely to the Selachii; others are nearer to the Dipnoans; others again represent a transition to the Teleostei. For our zoological purposes the most interesting are the intermediate forms between the Selachii and the Dipnoans. Huxley, to whom we owe particularly important work on the fossil Ganoids, classed them in the order of the *Crossopterygii*. Many genera and species of this order are found in the Devonian and Carboniferous strata (Fig. 252); a single, greatly modified survivor of the group is still found in the huge rivers of Africa (*Polypterus*, Fig. 253, and the closely related *Colemanichthys*). In many impressions of the *Crossopterygii* the *Snouting Mackerel* seems to be omitted,

and therefore wall
in the *Urodon* (behind the head).

Part of (these *Crossopterygii*) very closely in their chief anatomy to the Dipneusts, and thus represent phylogenetically the transition from the Devonian Ganoids to the earliest air-breathing vertebrates. This important advance was made in the Devonian period. The numerous fossils that we

the Laurentian and Cambrian periods, belong exclusively to aquatic plants and animals. From this paleontological fact, in conjunction with important geological and biological indications, we may infer with some confidence that there were no terrestrial animals at that time. During the whole of the vast archæozoic period—many millions of years—the living population of our planet consisted almost exclusively of aquatic organisms. This is a very remarkable fact, when we remember that this period embraces the larger half of the whole history of life. The lower animal-stems are wholly (or with very few exceptions) aquatic. Not the higher stems also remained in the water during the primordial epoch. It was only towards its close that some of them came to live on land. We find isolated fossil remains of terrestrial animals first in the Upper Silurian, and in larger numbers in the Devonian strata, which were deposited at the beginning of the second chief series of geology (the paleozoic ægæ). The number increase rapidly the Carboniferous and Permian deposits. We find many species both of the articulate and the vertebrate

land and breathed the atmosphere; their aquatic ancestors of the Silurian period only breathed water. This important change in respiration is the chief modification that the animal organism underwent in passing from the water to the solid land. The first was the formation of lungs for breathing air; up to that time the gills alone had served for respiration. But there was at the same time a great change in the circulation and its organs; these are always very closely correlated to the respiratory organs. Moreover, the limbs and other organs were also more

or less modified, either in consequence of remote correlation to the preceding or owing to new adaptations.

In the vertebrate stem it was unquestionably a branch of the fishes—in fact, of the Ganoids—that made the first fortunate expedition during the Devonian period of adapting themselves to terrestrial life and breathing the atmosphere. This is a modification of the heart and the lungs. The true fishes have merely a pair of blind olfactory pits on the surface of the head; but a connection of these with the cavity of the mouth was now formed, and a canal made its appearance on each side, and led directly from the nasal depression



FIG. 10.—Fossil of a Ganoid skull (*Ganoidichthys*) from the Devonian of Wales. (From Huxley.)

into the mouth-cavity, atmospheric air to the

lungs. Further, in all true fishes the heart has only two sections—an atrium that receives the venous blood from the veins, and a ventricle that propels it through a conical artery into the gills; the atrium was now divided into two halves, or right and left auricles, by an incomplete partition. The right auricle alone now received the venous blood from the body, while the left auricle received the venous blood that flowed from the lungs and gills to the heart. Thus the double circulation of the higher vertebrates was evolved from the simple

circulation of the true fishes, and, in accordance with the laws of circulation, this advance led to others in the structure of other organs.

The vertebrate class, that then adapted

they retained the earlier gill-respiration along with the new pulmonary (lung) respiration, till the lowest amphibians. This class was represented during the paleozoic age (or the Devonian, Car-

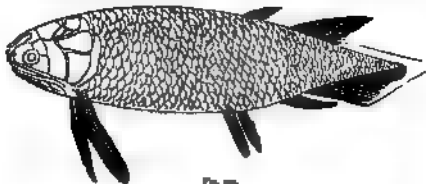


FIG. 225.

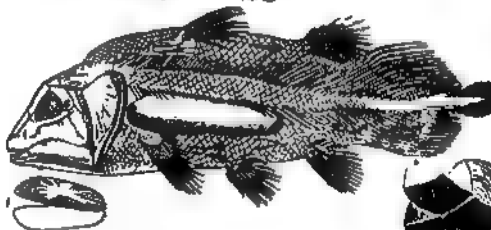


FIG. 226.



FIG. 227.

FIG. 225.—A Devonian Crustacean (*Elphidium sublineatum*), 6 (From Huxley).

FIG. 226.—A Devonian Crustacean (*Urolophus pinnatus*), from the of Zittel. 1, pincer; 2, pincer; 3, other appendage.

FIG. 227.—A Devonian Crustacean, from the Upper Silurian (*Elphidium*).

itself to breathing the atmosphere, and was developed from a branch Genoids, takes the name of the *Dipnoans* or *Dipnoans* ("double-breathers"), because

hemifrons, and Perciform; number of different genera only three genera of the to-day: *Protoperca*, *Perca*

of tropical Africa (the White Nile, the Niger, Quellimian, etc.), *Lepidosteus pernix* in tropical South America (in the tributaries of the Amazon), and *Ceratodus Forsteri* in the rivers of East Australia. This wide distribution of the three isolated survivors proves that they represent a group that was formerly very large. In their whole structure they

thoroughly now associate them with the fishes. As a matter of fact, the characters of the two classes are so far united in the Dipneustes that the answer to the question depends entirely on the definition we give of "fish" and "amphibian." In habits they are true amphibians. During the tropical winter, in the rainy season, they swim in the water like the fishes, and

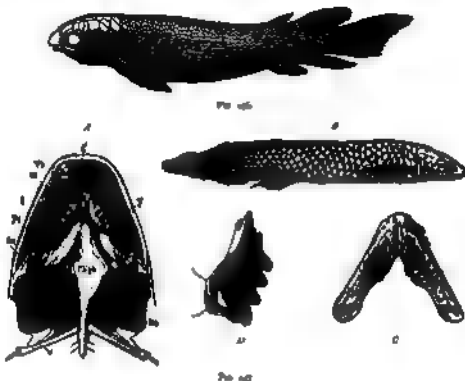


FIG. 456.—Fossil Dipneuste (*Dipneuste latidorsalis*) from the Silurian of Devon. (From Peck.)

FIG. 457.—The Australian Dipneuste (*Ceratodus Forsteri*). A, whole from the side. B, lower jaw of the whole. C, lower jaw (from a different specimen). D, quadrate bone. E, symplectrodont. F, teeth. G, broadest part of the fin. H, fin skin. I, broadest part of the fin. (From the Trustees.)

form a transition from the fishes to the amphibians. The transitional formation between the two classes is so pronounced in the whole organization of these remarkable animals that zoologists had a lively controversy over the question whether they were really fishes or amphibians. Several distinguished zoologists classed them with the amphibians,

because water by gills. During the dry season they bury themselves in the dry mud, and breathe the atmosphere through lungs, like the amphibians and the higher vertebrates. In this double respiration they resemble the lower amphibians, and have the same characteristic formation of the heart; in this they are much superior to the fishes. But in most other features

they approach nearer to the fishes, and are inferior to the amphibia. Evidently they are entirely fish-like.

In the Dipnoans the head is not marked off from the trunk. The skin is covered with large scales. The skeleton is soft, cartilaginous, and at a low stage of development, as in the lowest *Selachii* and the earliest *Ganoidei*. The chorda is completely retained, and surrounded by an unsegmented sheath. The two pairs of limbs are very simple legs of a primitive

skeleton; the cartilaginous skeleton of its two pairs of fins, for instance, has still the original form of a bi-serial or feathered leaf, and was on that account described by Gegenbaur as a "primitive fin-skeleton." On the other hand, the skeleton of the pairs of fins is greatly reduced in the African dipnoan (*Protopterus*) and the American (*Lepidosteus*). Further, the lungs are double in these modern dipnoans, as in all the other air-breathing vertebrates; they



FIG. 43.



FIG. 44.

FIG. 43.—Young *Ceratodus*, shortly after coming from the egg, enlarged and stained. (From Richard Owen.)

FIG. 44.—Young *Ceratodus*, as before, but showing the egg. A small fold of per. is rudimentary belly-fin. (From Richard Owen.)

type, like those of the lowest *Selachii*. The formation of the brain, the gut, and the sexual organs is also the same as in the *Selachii*. Thus the Dipnoans have preserved by heredity many of the less advanced features of our primitive fish-like ancestors, and at the same time have made a great step forward in adaptation to air-breathing by means of lungs and the correlative improvement of the heart.

Ceratodus is particularly interesting on account of the primitive build of its

body on that account been called "double-lunged" (*Dipnoan*) in contrast to the *Ceratodus*; the latter has only a single lung (*Monopneumon*). At the same time the gills also are developed as water-breathing organs in all these lung-fishes. *Protopterus* has external as well as internal gills.

The palaeozoic Dipnoans that are in the direct line of our ancestry, and form the connecting-bridge between the *Ganoidei* and the *Amphibia*, differ in many respects

from their living descendants, but agree with them in the above essential features. This is confirmed by a number of interesting facts that have lately come to our knowledge in connection with the

embryonic development of the *Ceratodus* and *Leptodus*; they give us important information as to the stem-history of the lower Vertebrates, and therefore of our early ancestors of the paleozoic age.

CHAPTER XXII.

OUR FIVE-TOED ANCESTORS

When the phylogenetic study of the four higher classes of Vertebrates, which must now engage our attention, we reach much firmer ground and more light in the construction of our genealogy than we have, perhaps, enjoyed up to the present. In the first place, we owe a number of very valuable data to the very interesting class of Vertebrates that comes next in the Dipneusta and have been developed from them—the Amphibia. To this group belong the salamander, the frog, and the toad. In earlier days all the reptiles were, on the example of *Lacerta*, classed with the Amphibia (lizards, serpents, crocodiles, and tortoises). But the reptiles are much more advanced than the Amphibia, and are nearer to the birds in the chief points of their structure. The true Amphibia are nearer to the Dipneusta and the fishes; they are also much older than the reptiles. There were plenty of highly-developed (and sometimes large) Amphibia during the Carboniferous period; but the earliest reptiles are only found in the Permian period. It is probable that the Amphibia were evolved even earlier—during the Devonian period—from the Dipneusta. The earliest Amphibia of which we have fossil remains show that rattlesnakes (very numerous especially in the Triassic strata) were distinguished for a graceful and cool or a powerful bony armour on the skin (like the crocodile), whereas the living amphibians have usually a smooth and slippery skin.

The earliest of these armoured Amphibia (*Pleurocoelidina*) form the order of *Stegocéphala* ("roof-headed") (Fig. 566). It is among these, and not among the actual Amphibia, that we must look for the forms that are directly related to the genealogy of our race, and are the ancestors of the three higher

classes of Vertebrates. But even the existing Amphibia have such important relations to us in their anatomical structure, and especially their embryonic development, that we may say: Between the Dipneusta and the Amniotes there was a series of extinct intermediate forms which we should certainly class with the Amphibia if we had them before us. In their whole organisation even the actual Amphibia seem to be an instructive transitional group. In the important respects of respiration and circulation they approach very closely to the Dipneusta, though in other respects they are far superior to them.

This is particularly true of the development of their limbs or extremities. In them we find them for the first time as five-toed feet. The thorough investigations of Gegenbaur have shown that the fish's fin, of which very erroneous opinions were formerly held, are many-toed feet. The various cartilaginous or bony radii that are found in large numbers in each fin correspond to the fingers or toes of the higher Vertebrates. The several joints of each fin-radius correspond to the various parts of the toe. Even in the Dipneusta the fin is of the same construction as in the fishes; it was afterwards gradually evolved into the five-toed foot, which we first encounter in the Amphibia. This reduction of the number of the toes to six, and then to five, probably took place in the second half of the Devonian period—at the latest, in the subsequent Carboniferous period—in those Dipneusta which we regard as the ancestors of the Amphibia. We have several fossil remains of five-toed Amphibia from this period. There are stambes of fossil impressions of them in the Triassic of Thuringia (*Chirotherium*).

The fact that the toe number five is of great importance, because they have clearly been transmitted from the Amphibia to all the higher Vertebrates. Man entirely resembles his amphibian

in well known that this hereditary number of the toes has assumed a very great practical importance from remote times; not in our whole system of nomenclature (the decimal system applied to measure-

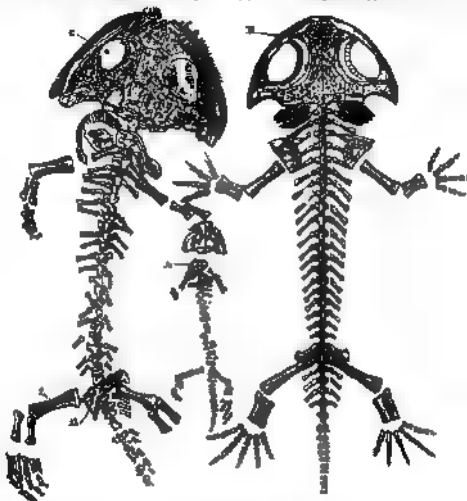


Fig. 10. *Temnodactylus* from the Puyallup, found in the Puyallup basin near Tacoma (*Neotoma* series *amphibioidea*). A. (From Cooper) A skeleton of a young larva. B. Larva, captured, with gills. C. The adult form, natural size.

ancestors in this respect, and indeed in the whole structure of the bony skeleton of his five-toed extremities. A careful comparison of the skeleton of the frog with our own is enough to show this. It

must of time, size, weight, etc.) is based. There is absolutely no reason why there should be five toes in the fore and hind feet in the lowest Amphibia, the reptiles, and the higher Vertebrates, unless we

scribe it to inheritance from a common stem-form. Heredity alone can explain it. It is true that we find less than five toes in many of the Amphibia and of the higher Vertebrates. But in all these cases we can prove that some of the toes atrophied, and were in time lost altogether.

The cause of this evolution of the five-toed foot from the many-toed fin in the amphibian ancestor must be sought in adaptation to the entire change of function that the limbs experienced in passing from an exclusively aquatic to a partly terrestrial life. The many-toed fin had been used almost solely for motion in the water; it had now also to support the body in creeping on the solid ground. This led to a modification both of the skeleton and the muscles of the limbs. The number of the fin-rays was gradually reduced, and sank finally to five. But those five remaining rays became much stronger. The soft cartilaginous rods became bony rods. The rest of the skeleton was similarly strengthened. Thus from the one-armed liver of the many-toed fish-fin arose the improved many-armed lever system of the five-toed amphibian limbs. The movements of the body gained in variety as well as in strength. The various parts of the skeletal system and correlated muscular system began to differentiate more and more. In view of the close correlation of the muscular and nervous systems, this also made great advance in structure and function. Hence we find, as a matter of fact, that the brain is much more developed in the higher Amphibia than in the fishes, the Dipnoata, and the lower Amphibia.

The first advance in organization that was occasioned by the adoption of life on land was naturally the construction of an organ for breathing air—a lung. This was formed directly from the floating-bladder inherited from the fishes. At first its function was immaterially beside that of the gills, the other organ for water-respiration. Hence we find in the lowest Amphibia, the gilled Amphibia, that, like the Dipnoata, they pass the greater part of their life in the water, and breathe water through gills. They only come to the surface at brief intervals, or creep on to the land, and then breathe air by their lungs. But some of the (talud Amphibia—the salamanders—remain entirely in the water when they are young, and afterwards spend most of their time on

land. In the adult state they only breathe air through lungs. The same applies to the most advanced of the Amphibia, the Batrachia (frogs and toads); some of these have entirely lost the gill-bearing larva form.* This is also the case with certain small, serpentine Amphibia, the Caecilia (which live in the ground like earth-worms).

The great interest of the natural history of the Amphibia consists especially in their intermediate position between the lower and higher Vertebrates. The lower Amphibia approach very closely to the



Fig. 46.—Larva of the spotted Salamander (*Ambystoma maculatum*), seen from the ventral side. In the anterior a yellowishish stage from the feet. The thickened gills were specifically modified. The two pairs of legs are still very small.

Dipnoata in their whole organization, live entirely in the water, and breathe by gills; but the higher Amphibia are just as close to the Amniotes, live mainly on land, and breathe by lungs. But in their younger state the latter resemble the former, and only reach the higher stage by a complete metamorphosis. The embryonic development of most of the

* The tadpoles of *Bombina* (*Bombina orientalis*) have the gills on the mouth, and the tail and yellowish on the outside of the body. On the mouth or head they often resemble the frog emerging from the egg.

higher Amphibia still faithfully reproduces the stem-history of the whole class, and the various stages of the evolution that was made by the lower Vertebrates in passing from aquatic to terrestrial life during the Devonian or the Carboniferous period are repeated in the spring of every frog that develops from an egg in our ponds.

The common frog leaves the egg in the shape of a larva, like the tailed salamander (Fig. 261), and this is altogether different



FIG. 261.—Anterior portion of the common pond-frog (*Rana temporaria*), or "tadpole." It usually is a form of ventral for swimming on its stomach, or else it swims with the gill-cover dorsally, but in the gill-clefts, from which the branching gills (*d*) protrude, a tail-ventral, or ectoneuric, fin-ridge is the rule.

from the mature frog (Fig. 262). The short trunk ends in a long tail, with the form and structure of a fish's tail (*a*). There are no limbs at first. The respiration is exclusively branchial, first through external (*b*) and then internal gills. In harmony with this the heart has the same structure as in the fish, and consists of two sections—an atrium that receives the venous blood from the body, and a ventricle that forces it through the interior into the gills.

We find the larvae of the frog (or tadpoles, *Gyrus*) in great numbers in our ponds every spring in this fish-form, using their muscular tails in swimming, just like the fishes and young Ascidia. When they have reached a certain size, the remarkable metamorphosis from the fish-form to the frog begins. A blind sac grows out of the gullet, and expands into a couple of spacious sacs: these are the lungs. The simple chamber of the heart is divided into two sections by the development of a partition, and there are at the same time considerable changes in the structure of the chief arteries. Previously all the blood went from the auricle through the aortic arches into the gills, but now only part of it goes to the gills, the other part passing to the lungs through the new-formed pulmonary artery. From this point arterial blood returns to the left auricle of the heart, while the venous blood gathers in the right auricle. As both auricles open into a single ventricle, this contains mixed blood. The dipneust form has now succeeded to the fish-form. In the further course of the metamorphosis the gills and the branchial vessels entirely disappear, and the respiration becomes exclusively pulmonary. Later, the long swimming tail is lost, and the frog now leaps to the land with the legs that have grown meantime.

This remarkable metamorphosis of the Amphibia is very instructive in connection with our human genealogy, and is particularly interesting from the fact that the various groups of actual Amphibia have remained at different stages of their development, in harmony with the biogenetic law. We have first of all a very low order of Amphibia—the *Sarcopterygians* ("gilled-amphibia"), which retain their gills throughout life, like the Eelae. In a second order of the salamanders the gills are lost in the metamorphosis, and when fully grown they have only pulmonary respiration. Some of the tailed Amphibia still retain the gill-clefts in the side of the neck, though they have lost the gills themselves (*Megapneustes*). If we force the larvae of our salamanders (Fig. 261) and prevent them from reaching the land, we can in favourable circumstances make them retain their gills. In this fish-like condition they reach sexual maturity, and remain throughout life at the lower stage of the gilled Amphibia.

We have the reverse of this experiment in a Mexican gilled salamander, the fish-like axolotl (*Siredon pacificus*). It was formerly regarded as a permanent gilled amphibian persisting throughout life at the fish-stage. But some of the hundreds of these animals that are kept in the Botanical Garden at Paris got on to the land for some reason or other, lost their gills, and changed into a form closely resembling the salamander (*Ambystoma*). Other species of the genus became sexually mature for the first time in this condition. This has been regarded as an astounding phenomenon, although every common frog and salamander repeats the metamorphosis in the spring. The whole change from the aquatic and gill-breathing animal to the terrestrial lung-breathing form may be followed step by step in this case. But what we

Their ancestors also had long tails and gills like the gilled Amphibia, as the tail and the gill-arches of the human embryo clearly show.

For comparative anatomical and ontogenetic reasons, we must not seek these amphibian ancestors of ours—as one would be inclined to do, perhaps—among the tail-less Ectacthyla, but among the tailed lower Amphibia.

The vertebrate form that comes next to the Amphibia in the series of our ancestors is a lizard-like animal, the earlier existence of which can be confidently deduced from the facts of comparative anatomy and ontogeny. The living *Hadronia* of New Zealand (Fig. 264) and the extinct *Phymatophis* of the Permian period (Fig. 265) are closely related to this important stem-form; we may call them the *Protosaurus*, or *Primitive Amniotes*.



FIG. 264.—*Hadronia*, tailed amphibian, from the Silurian Cadaver Reef (Sweden). (From Frölich.) The body tract is retained on the left.

we have in the development of the individual has happened to the whole class in the course of its stem-history.

The metamorphosis goes further to a third order of Amphibia, the *Batrachia* or *Aneura*, than in the salamander. To this belong the various kinds of toads, ringed snakes, water-frogs, tree-frogs, etc. These lose, not only the gills, but also (sooner or later) the tail, during metamorphosis.

The ontogenetic loss of the gills and the tail in the frog and toad can only be explained on the assumption that they are descended from long-tailed Amphibia of the salamander type. This is also clear from the comparative anatomy of the two groups. This remarkable metamorphosis is, however, also interesting because it throws a certain light on the phylogeny of the tail-less *Aneura* and *Aneura*.

All the Vertebrates above the Amphibia—i.e. the three classes of reptiles, birds, and mammals—differ so much in their whole organisation from all the lower Vertebrates we have yet considered, and have so great a resemblance to each other, that we put them all together in a single group with the title of *Amniotes*. In these three classes alone we find the remarkable embryonic membrane, already mentioned, which we called the *amnion*; a convergent adaptation that we may regard as a result of the sinking of the growing embryo into the yolk-sac.

All the Amniotes known to us—all reptiles, birds, and mammals (including man)—agree in so many important points of internal structure and development that their descent from a common ancestor can be affirmed with tolerable certainty. If the evidence of comparative

unity and category is over entirely beyond question, it is virtually the converse. All the particularities that accompany and follow the formation of the system, and that we have learned in our consideration of human embryology: all the particularities in the development of the organs which we will presently follow in detail, finally, all the principal special features of the internal structure of the full-grown *Amphioxus*—prove in exactly the common origin of all the *Amphioxus* from a single ancestor, namely that it is difficult to ascertain the idea of their evolution from several independent groups. This unknown common term-form in our Primitive *Amphioxus* (*Protamphioxus*). In outward appearance it was probably something between the teleostean and the lamprey.

It is very probable that some part of the Foreign period was the age of the origin of the *Protamphioxus*. This follows from the fact that the *Amphioxus* are actually developed until the Cretaceous period, and that the first fossil species (*Paleoamphioxus*, *Heteromphioxus*, *Protamphioxus*) are found towards the close of the Permian period. Among the important changes of the vertebrate organization that marked the rise of the first *Amphioxus* from subvertebrate *Amphioxus* during this period the following have to especially noteworthy: the great development of the water-breathing gills and the conversion of the gill-arches into solid organs, the formation of the bladder or primitive urinary sac, and the development of the ear.

One of the most evident characteristics of the *Amphioxus* is the complete loss of the gills. All *Amphioxus*, in view of living in water (such as sea-carpenter and whelk), breathe air through lungs, never water through gills. All the *Amphioxus* (with very rare exceptions) retain their gills for some time when young, and have for a time (if not permanently) branched rudiments, but after this there is no question of branched respiration. The *Protamphioxus* itself must have entirely abandoned water-breathing. Nevertheless, the gill-arches are preserved by heredity, and develop into totally different (in part rudimentary) organs—various parts of the bones of the tongue, the bones of the jaws, the organ of hearing, etc. But we do not find in the embryo of the *Amphioxus* any trace of gill-tissue, or of real respiratory organs in the gill-arches.

With this complete abandonment of the gills is probably connected the formation of another organ, to which we have already referred in embryology—namely, the intestine as primitive urinary sac (cf. p. 241). It is very probable that the urinary bladder of the *Dipodomys* is the first structure of the *Amphioxus*. We find in these a urinary bladder that proceeds from the lower wall of the hind end of the gut, and serves as a receptacle for the renal secretion. This organ has been communicated to the *Amphioxus*, &c. &c. and was in the frog.

The formation of the intestine and the complete disappearance of the gills are the most characteristic changes during the *Amphioxus* from the lamprey or *Verbrachius* to the sea-horse. To these we may add several other changes that are characteristic of all the *Amphioxus*, and are found in three only. One striking embryonic character of the *Amphioxus* is the great curve of the head and neck in the embryo. We also find an advance in the structure of several of the internal organs of the *Amphioxus* which raises them above the highest of the *Verbrachius*. In particular, a portion is forced in the simple structure of the heart, divided into right and left chambers. In connection with the complete metamorphosis of the gill-arches we find a factor for the presence of the embryonic organs. Also, there is a great advance in the structure of the brain, skeleton, muscular system, and other parts. Finally, one of the most important changes in the metamorphosis of the embryo. In all the earlier *Verbrachius* we have found the primitive kidneys as rudimentary organs, and these appear at an early stage in the embryo of all the higher *Verbrachius* up to man. But in the *Amphioxus* these primitive kidneys cease to act at an early stage of embryonic life, and their function is taken up by the permanent or secondary kidneys, which develop from the terminal masses of the proximal ducts.

Taking all these particularities of the *Amphioxus* together, it is impossible to doubt that all the members of this group—all cephalopods, birds, and mammals—have a common origin, and form a single blood-related group. Our own race belongs to this group. None is in every feature of his organization and embryonic development, a true *Amphioxus*, and has descended from the *Protamphioxus* with all the other

Amniotes. Though they appeared at the end (possibly even in the middle) of the Paleozoic age, the Amniotes only reached their full development during the Mesozoic age. The birds and mammals made their first appearance during this period. Even the reptiles show their greatest growth at this time, so that it is called "the reptile age." The extinct Protomole, the ancestor of the whale group,

and only known in contact with the Mammals at its root, is the combined group of the reptiles and birds; these two classes may, with Huxley, be conveniently grouped together as the *Sauropsida*. Their common stem-form is an extinct lizard-like reptile of the order of the *Rhynchocephala*. From this have been developed in various directions the serpents, crocodiles, tortoises, etc.—in a



Fig. 41.—The Kangaroo (Macropus giganteus—*Macropus giganteus*) of New Zealand. The mole-eating possum (Phalanger).

belongs in its whole organization to the reptile class.

The genealogical tree of the amniotic group is clearly indicated in its chief lines by their paleontology, comparative anatomy, and ontogeny. The group succeeding the Protomole divided into two branches. The branch that will claim our whole interest is the class of the Mammals. The other branch, which developed in a totally different direction,

word, all the members of the reptile class. But the remarkable class of the birds has also been evolved directly from a branch of the reptile group, as is now established beyond question. The embryos of the reptiles and birds are identical until a very late stage, and have an astonishing resemblance even later. Their whole structure agrees so much that no aptomatist now questions the descent of the birds from the reptiles. On the other

head, the mammal line has descended from the group of the *Sauromammalia*, a different branch of the *Proraptilia*. It is connected at its deepest roots with the reptile line, but it then diverges completely from it and follows a distinctive development. Man is the highest outcome of this class, the "crown of creation." The hypothesis that the three higher Vertebrate classes represent a single Amniote-stem, and that the common root of this stem is to be found in the amphibian class, is now generally admitted.

The instructive group of the Permian *Troosaurus*, the common root from which the divergent stems of the *Sauropsida* and *Mammalia* have issued, merits our particular attention as the stem-group of all the Amniotes. Fortunately a living representative of this extinct ancestral

sig), of which well-preserved skeletons are found in the Solenhofen schists, is perhaps still more closely related to them.

Unfortunately, the numerous fossil remains of Permian and Triassic *Troosaurus* that we have found in the last two decades are, for the most part, very imperfectly preserved. Very often we can make only precarious inferences from these skeletal fragments as to the anatomic characters of the soft parts that went with the bony skeleton of the extinct *Troosaurus*. Hence it has not yet been possible to arrange these important fossils with any confidence in the ancestral series that descend from the *Protomammals* to the *Sauropsids* on the one side and the *Mammals* on the other. Opinions are particularly divided as to the place in classification and the phylogenetic significance of the remarkable *Theromorphs*



FIG. 265.—*Troosaurus paludicola*, a Jurassic reptile from Walsleben. (From Hilde)

group has been preserved to our day; this is the remarkable *Basilosaurus* of New Zealand, *Hesperomys punctatus* (Fig. 264). Externally it differs little from the ordinary lizard; but in many important points of internal structure, especially in the primitive construction of the vertebral column, the skull, and the limbs, it occupies a much lower position, and approaches its amphibian ancestors, the *Stegomorphs*. Hence *Hesperomys* is the phylogenetically oldest of all living reptiles, an isolated survivor from the Permian period, closely resembling the common ancestor of the Amniotes. It must differ so little from this extinct form, our hypothetical *Protomammal*, that we put it next to the *Proraptilia*. The remarkable Permian *Paleosaurus*, that Cope discovered in the Platten terrain at Dresden in 1844, belongs to the same group (Fig. 263). The Jurassic genus *Amnosaurus* (Fig.

Cope gives this name to a very interesting and extensive group of extinct terrestrial reptiles, of which we have only fossil remains from the Permian and Triassic strata. Forty years ago some of them *Theromorphs* (fresh-water animals) were described by Owen as *Amniotes*. But during the last twenty years the distinguished American paleontologists, Cope and Osborn, have greatly increased our knowledge of them, and have claimed that the stem-forms of the *Mammals* must be sought in this order. As a matter of fact, the *Theromorphs* are nearer to the *Mammals* in the chief points of structure than any other reptiles. This is especially true of the *Therodonts*, to which the *Perosaurus* and *Pelycosaurus* belong (Fig. 267). The whole structure of their paws and hind-feet has attained the same form as in the *Monotremes*, the lowest *Mammals*. The formation of the

scapula and the quadrato bone show an approach to the Mammals such as we find in no other group of reptiles. The teeth also are already divided into incisors, canines, and molars. Nevertheless, it is very doubtful whether the Therapsoids really are in the ancestral line of the Sauromammals, or lead direct from the Tocoosaurs to the earliest Mammals. Other experts on this group believe that it is an independent legion of the reptiles, connected, perhaps, at its lowest root, with the Sauromammals, but developed quite independently of the Mammals—though parallel to them in many ways.

One of the most important of the zoological facts that we rely on in our investigation of the genealogy of the human race is the position of man in the Mammal class. However different the views of zoologists may have been as to this position in detail, and as to his relations to the apes, no scientist has ever doubted that man is a true mammal in his whole organization and development. Linné drew attention to this fact in the first edition of his famous *Sytema Naturæ* (1733). As will be seen in any museum of anatomy or any manual of comparative anatomy, the human frame has all the characteristics that are common to the Mammals and distinguish them conspicuously from all other animals.

If we examine this undoubted fact from the point of view of phylogeny, in the light of the theory of descent, it follows at once that man is of a common stem with all the other Mammals, and comes from the same root as they. But the various features in which the Mammals agree and by which they are distinguished are of such a character as to make a polyphyletic hypothesis quite inadmissible. It is impossible to entertain the idea that all the living and extinct Mammals come from a number of separate roots. If we accept the general theory of evolution, we are bound to admit the monophyletic hypothesis of the descent of all the Mammals (including man) from a single mammalian stem-form. We may call this long extinct root-form and its earliest descendants (a few genera of one family) "primitive mammals" or "stem-mammals" (*Pro-mammalia*). As we

have already seen, this root-form developed from the primitive Proreptile stem in a totally different direction from the birds, and soon separated from the main stem of the reptiles. The differences between the Mammals and the reptiles and birds are so important and characteristic that we can assume with complete confidence this division of the vertebrates about at the commencement of the development of the Amniotes. The reptiles and birds, which we group together as the *Sauropsoids*, generally agree in the characteristic structure of the skull and brain, and this is notably different from that of the Mammals. In most of the reptiles and birds the skull is connected with the first cervical vertebra (the *axis*)



FIG. 46.—Skull of a Puzosaurus (*Puzosaurus latissimus*). 1, Upper jawbone; 2, small bone of lower jaw; 3, lower jawbone, in quadrilateral form, as in reptiles; 4, small bone of lower jaw, as in mammals.

by a single, and in the Mammals (and *Amphibia*) by a double, condyle at the back of the head. In the former the lower jaw is composed of several pieces, and connected with the skull so that it can move by a special maxillary bone (the *quadrate*); in the Mammals the lower jaw consists of one pair of bony pieces, which articulate directly with the temporal bone. Further, in the Sauropsoids the skin is clothed with scales or feathers; in the Mammals with hair. The red blood-cells of the former have a nucleus; those of the latter have not. In fine, two quite characteristic features of the Mammals, which distinguish them not only from the birds and reptiles, but from all other animals, are the possession of a

important phylogenetic theme: The Monodelphia or Placentalia descended from the Didelphia or Marsupialia; and the latter, in turn, are descended from the Monotremes or Ornithodelphia.

Thus we must regard as the twenty-first stage in our genealogical tree the earliest and lowest chief group of the Monotremata—the selection of the Monotremata "class-animal," Ornithodelphia, or Protochiria, (Figs. xiv and xv). They take their name from the cloaca which they share with all the lower Vertebrata. This cloaca is the common outlet for the passages of the excrement, the urine, and the sexual products. The urinary bladder and sexual canal open into the basement part of this gut, while in all the other Monotremata they are separated from the rectum and anus. The latter have a special gonopodium (a member of the gonopodium). The bladder when open into the cloaca in the Monotremata, and, indeed, apart from the two urinary ducts; in all the other Monotremata the latter open directly into the bladder. It was proved by Huxley and Cuvier that the Monotremata lay large eggs like the reptiles, while all the other Monotremata are viviparous. In this Richard Owen further proved that these large eggs, rich in food-yolk, have a partial yolk-sacculum and demand germination, as I had hypothetically assumed in 1870, have again they resemble their reptilian ancestor. The construction of the urinary gland in the peculiar in the Monotremata. In them the glands have no vents for the young animal to excrete, but there is a special part of the bladder pierced with holes like a sieve, from which the milk issues, and the young Monotremata suck it off. Further, the mode of the Monotremata is very little advanced. It is further that that of any of the other Monotremata. The fore-limbs are overhanging, in particular, is so small that it does not cover the carpal bones. In the skeleton (Fig. xv) the formation of the scapula, saving other parts in common, is quite different from that of the other Monotremata, and rather agrees with that of the reptiles and Amphibia. Like them, the Monotremata have a strongly developed canaliculus. From these and other less prominent characteristics it follows absolutely that the Monotremata occupy the lowest place among the Monotremata, and represent a transitional group between the Therapsida and the

rest of the Monotremata. All these remarkable captious characters must have been possessed by the stem-form of the whole mammalian class, the Protomammalia of the Triassic period, and have been inherited from the Protocyptheria.

During the Triassic and Jurassic periods the sub-class of the Monotremata was represented by a number of different stem-monotremata. Numerous fossil remains of them have lately been discovered in the Mesozoic strata of Europe, Africa, and America. To-day there are only two surviving specimens of the group, which are placed together in the family of the duck-bills, Ornithorhynchidae. They are confined to Australia and the neighbouring island of Van Diemen's Land (or Tasmania); they lay eggs larger every year, and with them, like their blood-relatives, lay among the earliest animals. One form lives in the rivers,



Fig. xiv.—Lower jaw of a Platypus (Ornithorhynchidae) (Ornithorhynchidae) from the North American Triassic. (Huxley, a similar specimen is shown.) (From Huxley.)

and builds subterranean dwellings on the banks; then in the Ornithorhynchidae, which builds its nest in a thick mud bar, and breeds its young, which look very much like the bill of a duck (Figs. xvi, xvii). The other form, the land duck-bill, or spiny ant-eater (Echidna spinosa), is very much like the ant-eater in its habits and the peculiar construction of its thin coat and very long tongue; it is covered with scales, and can roll itself up like a hedgehog. A separate form (Peroryzops) has lately been found in New Guinea.

These modern Ornithorhynchidae are the earliest survivors of the vast Mesozoic group of Monotremata; hence they have the most interest in connection with the history of the Monotremata as the living stem-creature (Huxley) for that of the reptiles, and the isolated Acrodon (Amphibian) for the phylogeny of the Vertebrate stem.

The Australian duck-bills are distinguished externally by a sensitive third

like beak or snout. This absence of real bony teeth is a late result of adaptation, as in the toothless Placental (Squirrels, armadillos and ant-eaters). The extinct Monotremes, to which the *Prozansauroids* belonged, must have had developed teeth, inherited from the reptiles. Lastly small rudiments of real molars have been discovered in the young of the *Ornitho-*

Marsupials retain a great part of the characteristics of the Monotremes, they



FIG. 219.—The *Ornithomimus* at *Hadronia*. (*Ornithomimus* *hadronia*.)

rhynchus, which has horny plates in the jaws instead of real teeth.

The living *Ornithomimus* and the stem-forms of the *Marsupials* (or *Didelphids*) must be regarded as two widely diverging lines from the *Prozansauroids*. This second sub-class of the *Mammalia* is very interesting as a perfect intermediate stage between the other two. While the



FIG. 220.—Skeleton of the primate.

have also acquired some of the chief features of the *Placental*. Some features

are also peculiar to the Marsupials, such as the construction of the male and female sexual organs and the form of the lower jaw. The Marsupials are distinguished by a peculiar hook-like bony process that hangs from the corner of the lower jaw and points inward. As most of the Placentals have not this process, we can, with some probability, recognize the Marsupial from its structure alone. Most of the mammalian remains that we have from the Jurassic and Cretaceous deposits are merely lower jaws, and most of the jaws found in the Tertiary deposits at Stonesfield and Furber have the peculiar hook-like process that characterizes the lower jaw of the Marsupial. On the strength of this paleontological fact, we may suppose that they belonged to Marsupials. Placental do not seem to have arisen at the middle of the Mesozoic age—not until towards its close (in the Cretaceous period). At all events, we have no fossil remains of indubitable Placentals from that period.

The existing Marsupials, of which the plant-eating kangaroos and the carnivorous opossums (Fig. 272) are the best known, differ a good deal in structure, shape, and size, and correspond in many respects to the various orders of Placentals. Most of them live in America, and a small part of the Australian and East Malayan islands. There is now not a single living Marsupial on the mainland of Europe, Asia, or Africa. It was very different during the Mesozoic and even during the Cretaceous age. The sedimentary deposits of these periods contain a great number and variety of marsupial remains, sometimes of a colossal size, in various parts of the earth, and even in Europe. We may infer from this that the existing Marsupials are the remnant of an extensive earlier group that was distributed all over the earth. It had to give way in the struggle for life to the more powerful Placentals during the Tertiary period. The survivors of the group were able to keep alive in Australia and South America because the one was completely separated from the other parts of the earth during the whole of the Tertiary period, and the other during the greater part of it.

From the comparative anatomy and analogy of the existing Marsupials we may draw very interesting conclusions as to their intermediate position between

the earlier Mesozoic and the later Placentals. The defective development of the brain (especially the cerebrum), the possession of marsupial bones, and the simple construction of the allantois (without any placenta as yet) were inherited by the Marsupials, with many other features, from the Mesozoic, and preserved. On the other hand, they have lost the independent form (coracoid bone) of the shoulder-blade. But we have a more important advance in the disappearance of the clitoris; the rectum and anus are separated by a partition from the uro-genital opening (*anus separatus*). Moreover, all the Marsupials have such an accessory gland, at which the new-born animal sucks. The spots pass into the cavity of a pouch or pocket on the ventral side of the mother, and this is supported by a couple of mammae below. The young are born in a very imperfect condition, and carried



FIG. 271.—Lower jaw of a *Progomphosaurus* (Dinosaurian group) from the Jurassic of the Solothurn (Switzerland).

by the mother for some time longer in her pouch, until they are fully developed (Fig. 272). In the giant kangaroo, which is as tall as a man, the embryo only develops for a month in the uterus, is then born in a very imperfect state, and finishes its growth in the mother's pouch (*marsupium*); it remains in that abode nine months, and at first hangs continually on to the teat of the mammae gland.

From these and other characteristics (especially the peculiar construction of the internal and external sexual organs in male and female) it is clear that we must conceive the whole sub-class of the Marsupials as one stem group, which has been developed from the Progomphomials. From one branch of these Marsupials (possibly from more than one) the stem-forms of the higher Mammalia, the Placentals, were afterwards evolved. Of the existing forms of the Marsupials,

which have undergone various modifications through adaptation to different environments, the family of the opossums (*Didelphida* or *Prosimiina*) appear to be the oldest and nearest to the primitive stem-form of the whole class. To this family belong the grab-eating opossum of Brazil (Fig. 272) and the opossum of

Lesser, were evolved directly from the opossum. We must not forget, however, that the conversion of the five-toed foot into a prehensile hand is polyphyletic. By the same adaptation to climbing trees the habit of grasping their branches with the feet has in many different cases brought about that opposition of the



FIG. 272.—The grab-eating Opossum (*Didelphis aurita*). The female has three young in the pouch. (From Storer.)

Virginia, on the embryology of which Selous has given us a valuable work (cf. Figs. 63-7 and 232-5). These Didelphids climb trees like the apes, grasping the branches with their hand-shaped hind feet. We may conclude from this that the stem-form of the *Prosimiina*, which we must regard as the earliest

limb or great toe to the other toes which makes the hand prehensile. We see this in the climbing lizards (*Chamaeleon*), the birds, and the tree-dwelling mammals of various orders.

Some zoologists have lately advanced the opposite opinion, that the *Marxipials* represent a completely independent sub-

class of the *Marsupials*, with no direct relation to the *Placentals*, and developing independently of them from the *Monotremes*. But this opinion is untenable if we examine carefully the whole organization of the three sub-classes, and do not lay the chief stress on incidental features and secondary adaptations (such as the

formation of the marsupium). It is then clear that the *Marsupials*—viviparous *Mammals* without placenta—are a necessary intermediate from the oviparous *Monotremes* to the higher *Placentals* with chorion-villa. In this sense the *Marsupial* class certainly contains some of man's ancestors.

CHAPTER XXIII.

OUR APE ANCESTORS

THE long series of animal forms which we must regard as the ancestors of our race has been confined within narrower and narrower circles in our phylogenetic inquiry, has progressed. The great majority of known animals do not fall in the line of our ancestry, and even within the vertebrate stem only a small number prove found to do so. In the same old animal class of the stem, the *Chondrichthyes*, there are only a few families that belong directly in our genealogical tree. The most important of these are the *Apes* and their predecessors, the *Haploids*, and the various *Placentals* (*Protherians*).

The *Placentals* (also called *Eutheria*, *Monodelphia*, *Archia* or *Euphonia*) are distinguished from the lower mammals we have just considered, the *Monotremes* and *Marsupials*, by a number of striking particularities. Man has all these distinctive features, that is a very significant fact. We may, on the ground of the most careful comparative-anatomical and ontogenetic research, formulate the thesis: "Man is in every respect a true *Placental*." He has all the characteristics of structure and development that distinguish the *Placentals* from the two lower divisions of the mammals, and, hence, from all other animals. Among these characteristics we must especially notice the more advanced development of the brain. The fore-brain or cerebrum especially is much more developed in them than in the lower animals. The *corpus callosum*, which forms a sort of wide bridge connecting the two hemispheres of the cerebrum, is only fully formed in the

Placentals; it is very rudimentary in the *Marsupials* and *Monotremes*. It is true that the lower *Placentals* are not far removed from the *Marsupials* in cerebral development, but within the placental group we can trace an unbroken gradation of progressive development of the brain, rising gradually from the lowest stage up to the elaborate psychic organ of the *Apes* and man. The human soul—a physiological function of the brain—is really only a more advanced *Apes*-soul.

The mammary glands of the *Placentals* are provided with their like tubes of the *Marsupials*, but we never find in the *Placentals* the pouch in which the latter carry and suckle their young. Nor have they the marsupial bones in the ventral wall at the anterior base of the pelvis, which the *Marsupials* have in common with the *Monotremes*, and which are formed by a partial ossification of the ends of the inner oblique abdominal muscle. There are merely a few insignificant remnants of them in some of the *Carnivora*. The *Placentals* are also generally without the hook-shaped process at the angle of the lower jaw which is found in the *Marsupials*.

However, the feature that characterizes the *Placentals* above all others, and that has given its name to the whole subclass, is the formation of the placenta. We have already considered the formation and significance of this remarkable embryonic organ when we traced the development of the chorion and the allantois in the human embryo (pp. 168-9). The twinning sac or the allantois, the

the uterus disappears, wide cervices filled with maternal blood appear, and here these the chorion-villi of the embryo penetrate. The sum of these vessels of both kinds, that are so intimately correlated at this point, together with the connective and enveloping tissue, is the *placenta*. The placenta consists, therefore, properly speaking, of two different though intimately connected parts—the fetal placenta (Fig. 273 *che*) within and the maternal or uterine placenta (*phc*) without. The latter is made up of the mucous coat of the uterus and its blood-vessels, the former of the villi chorion and the umbilical vessels of the embryo (of Fig. 196).

The manner in which these two kinds of vessels combine in the placenta, and the structure, form, and use of it, differ a good deal in the various Placentals; so some suggest they give us valuable data

at birth the fetal placenta alone comes away; the maternal placenta is not torn away with it.

The formation of the placenta is very different in the second and higher section of the Placentals, the *Deciduatæ*. Here again the whole surface of the chorion is thickly covered with the villi in the beginning. But they afterwards disappear from one part of the surface, and grow proportionately thicker on the other part. We thus get a differentiation between the smooth chorion (*chorion laeve*, Fig. 273 *chi*) and the thickly-cuffed chorion (*chorion frondosum*, Fig. 273 *chf*). The former has only a few small villi or none at all, the latter is thickly covered with large and well-developed villi; this alone now constitutes the placenta. In the great majority of the *Deciduatæ* the placenta has the same shape as in man (Figs. 199, 200)—namely

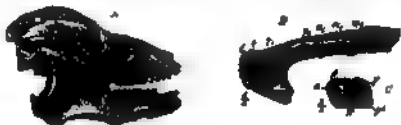


Fig. 273.—Wall of a Fetal Sac (*Alouatta palliata*), from the Museum of Genoa. A lateral view from the right, full natural size. B, wall of part. C, fetal surface. D, chorion. E, chorion. F, chorion. G, chorion. H, chorion. I, chorion. J, chorion. K, chorion. L, chorion. M, chorion. N, chorion. O, chorion. P, chorion. Q, chorion. R, chorion. S, chorion. T, chorion. U, chorion. V, chorion. W, chorion. X, chorion. Y, chorion. Z, chorion.

for the natural classification, and therefore the phylogeny, of the whole of the subclass. On the ground of these differences we divide it into two principal sections; the lower Placentals or *Prosimiæ*, and the higher Placentals or *Deciduatæ*.

To the *Prosimiæ* belong three important groups of mammals: the Lemnians (*Prosimiæ*), the Ungulates (tapirs, horses, pigs, ruminants, etc.), and the Cetaceans (dolphins and whales). In these *Prosimiæ* the villi are distributed over the whole surface of the chorion (or its greater part), either singly or in groups. They are only loosely connected with the mucous coat of the uterus, so that the whole placental membrane with its villi can be easily withdrawn from the uterine depression like a hand from a glove. There is no real coalescence of the two placentas at any part of the surface of contact. Hence

a thick, circular disk like a cake; so we find in the Insectivora, Chiroptera, Rodents, and Apes. This *placenta* lies on one side of the chorion. But in the *Deciduatæ* (both the Carnivora and the seals, *Pinnipedia*) and in the elephant and several other *Deciduatæ* we find a *synplacenta*; in these the rich mass of villi runs like a girdle round the middle of the elliptical chorion, the two poles of it being free from them.

Still more characteristic of the *Deciduatæ* is the peculiar and very intimate connection between the *chorion frondosum* and the corresponding part of the mucous coat of the womb, which we must regard as a real coalescence of the two. The villi of the chorion push their branches into the blood-filled tissues of the coat of the uterus, and the vessels of each loop together so intimately that it is no longer possible to separate the fetal

from the maternal placenta; they form henceforth a compact and apparently simple placenta. In consequence of this coalescence, a whole piece of the lining of the womb comes away at birth with the foetal membrane that is interlaced with it. This piece is called the "falling-away" membrane (*decidue*). It is also called the *acrom* (*apocry*) membrane, because

the *Decidua*tes. (Cf. Figs. 199, 200, pp. 263-70.)

In the various orders of the *Decidua*tes the placenta differs considerably both in outer form and internal structure. The extensive investigations of the last ten years have shown that there is more variation in these respects among the higher mammals than was formerly supposed. The physiological work of the important embryonic organ, the nutrition of the foetus during its long sojourn in the womb, is accomplished in the various groups of the *Placental* by very different and sometimes very elaborate structures. They have lately been fully described by Huxford.

The physiology of the placenta has become more intelligible from the fact that we have found a number of transitional forms of it. Some of the *Marupial* (*Primate*) have the beginning of a placenta. In some of the *Lorises* (*Primate*) a divided placenta with decidua is developed.

While these important results of comparative embryology have been throwing further light on the close blood-relationship of man and the anthropoid apes in the few years (p. 172), the great advance of paleontology has at the same time been affording us a deeper insight into the stem-history of the *Placental* group. In the seventh chapter of my *Systematic Phylogeny of the Vertebrata* I advanced the hypothesis that the *Placental* form a single stem with many branches, which has been evolved from an older group of the *Marupial* (*Primate*).

The four great legions of the *Placental*—*Rodents*, *Ungulates*, *Carnivora*, and *Primates*—are sharply separated to-day by important features of organization. But if we consider their extinct ancestors of the Tertiary period, the differences gradually disappear, the deeper we go in the Cretaceous deposits; in the end we find that they vanish altogether.



FIG. 215.—The younger form (*Alouatta palliata*) of *Capitula*, a

it is pierced like a sieve or sponge. All the higher *Placental* that have the decidua are clasped together as the "*Decidua*tes." The tearing away of the decidua at birth naturally causes the mother to lose a quantity of blood, which does not happen in the *Inducta*tes. The lost part of the uterine coat has to be replaced by a new growth after birth in

The primitive stem-form of the Rodents (*Eurotychida*), the Ungulates (*Chamylanthra*), the Carnassals (*Ichthyoda*), and the Primates (*Lemurina*) are so closely related at the beginning of the Tertiary period that we might group them together as different families of one order, the Proplacentalia (*Mallotheria* or *Prochordata*).

Hence the great majority of the Placentalia have no shared and close relationship to man, but only the legacy of the Primates. This is now generally divided into three orders—the half-apes (*Prosimia*), apes (*Simia*), and man (*Anthropi*). The lemurs or half-apes are the stem-group, descending from the older *Mallotheria* of the Cretaceous period. From them the apes were isolated in the Tertiary period, and man was formed from them towards its close.

The Lemurs (*Prosimia*) have few living representatives. But they are very interesting, and are the last survivors of a once extensive group. We find many fossil remains of them in the older Tertiary deposits of Europe and North America, in the Eocene and Miocene. We distinguish two sub-orders, the fossil *Lemuroidea* and the modern *Lemurina*. The earliest and most primitive forms of the Lemurina are the *Pachymeris* (*Hypomys*), they come next to the earliest Placentalia (*Prochordata*), and have the typical full dentition, with forty-two teeth ($2.1.3$). The *Neotomaria* (*Adapida*, fig. 54) have only forty teeth, and have lost an incisor in each jaw ($2.2.2$). The dentition is still further reduced in the *Lemurina* (*Aotomaria*), which usually have only thirty-six teeth ($2.2.2$). These living varieties are scattered far over the southern part of the Old World. Most of the species live in Madagascar, some in the Sundi Islands, others on the mainland of Asia and Africa. They are gregarious and melanoleptic animals. They live a quiet life, climbing trees, and eating fruit and insects. They are of different kinds. Some are closely related to the Murripials (especially the *opossum*). Others (*Macrotars*) are nearer to the Inactivora, others again (*Canomy*) to the Rodentia. Some of the Lemurs (*Archelaris*) approach closely to the true apes. The numerous fossil remains of half-apes and apes that have been recently found in the Tertiary deposits justify us in thinking that our ancestors were represented by several different

species during this long period. Some of these were almost as big as man, such as the colossal *Lemuragonia Megaladaps* of Madagascar.

Next to the lemurs come the true apes (*Simia*), the twenty-eighth stage in our ancestry. It has been beyond question for some time now that the apes approach nearest to man in every respect of all the animals. Just as the lowest apes come close to the lemurs, so the highest come next to man. When we carefully study the comparative anatomy of the apes and man, we can trace a gradual and uninterrupted advance in the organization of the ape up to the purely human frame, and, after impartial examination of the "ape-



FIG. 54.—The unknown ape (*Prochordata*).

problem" that has been discussed of late years with such passionate interest, we come inevitably to the important conclusion, first surmised by Huxley in 1853: "Whatever systems of organs we take, the comparison of their modifications in the series of apes leads to the same result: that the systematic differences that separate man from the gorilla and chimpanzee are not so great as those that separate the gorilla from the lower apes." Translated into phylogenetic language, this "pithanocriticism," formulated in such masterly fashion by Huxley, is quite equivalent to the popular saying "Man is descended from the apes."

In the very first exposition of his profound natural classification (1735) Linné

placed the anthropoid mammals at the head of the animal kingdom, with three genera: man, the ape, and the sloth. He afterwards called them the "Primates"—the "lords" of the animal world; he then also separated the lemur from the true ape, and rejected the sloth. Later zoologists divided the order of Primates

and Quadrumana was retained by Cuvier and most of the subsequent zoologists. It seems to be extremely important, but, as a matter of fact, it is totally wrong. This was first shown in 1863 by Huxley, in his famous *Man's Place in Nature*. On the strength of careful comparative-anatomical research he proved that the

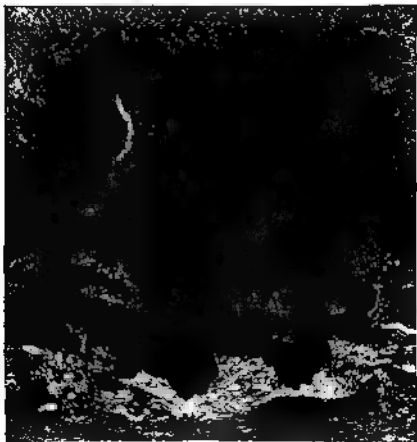


FIG. 27.—The drill-bitman (*Cynopithecus brevirostris*). (From Broder.)

First the Göttingen anatomist, Blumenbach, founded a special order for man, which he called *Bimans* ("two-handed"); in a second order he united the apes and lemurs under the name of *Quadrumana* ("four-handed"); and a third order was formed of the distantly-related *Corytopithecus* (bats, etc.). The separation of the *Bimans*

apes are just as truly "two-handed" as man; or, if we prefer to reverse it, that man is as truly four-handed as the ape. He showed convincingly that the ideas of hand and foot had been wrongly defined, and had been improperly based on physiological instead of morphological grounds. The circumstances that we oppose the

think to the other few fingers in our hand, and as our grasp things, seemed to be a special distinction of the hand is contrast to the feet, in which the corresponding great toe seems to oppose in this way to the others. But the ape can grasp with the hind-foot as well as the fore, and is were regarded as quadrumanous. However, the inability to grasp that we find in the foot of civilized man is a consequence of the habit of clothing it with tight coverings for thousands of years. Many of the hair-footed lower races of man, especially among the Negroes, use the feet very freely in the same way as the hand. As a result of early habit and continued practice, they can grasp with the foot (in climbing trees, for instance) just as well as with the hand. These non-habit Indians of our own men can grasp very strongly with the great toe and hold a spear with it as firmly as with the hand. Hence the physiological distinction between hand and foot can neither be pressed very far, nor has it a scientific basis. We must look to morphological characters.

As a matter of fact, it is possible to draw such a sharp morphological distinction—a distinction based on bony structure—between the feet and hand structure. In the formation both of the lower extremity and of the manus that are connected with the hand and foot bones and behind there are material and essential differences, and these are found both in man and the ape. For instance, the number and arrangement of the smaller bones of the hand and foot are quite different. There are certain essential differences in the muscles. The hand skeleton always has three sections (a short lesser wrist, a short carpal structure, and a long metacarpal) that are not found in the foot extremity. The arrangement of the muscles also is different before and behind. These characteristic differences between the feet and hand extremities are found in man as well as in the ape. There can be no doubt, therefore, that the ape's feet differ from those just as much as the human feet, and that all true apes are just as "bimane" as man. The complete distinction of the ape as "quadrumanous" is altogether wrong morphologically.

But it may be asked whether, quite apart from this, we can find any other features that distinguish man more sharply from the ape than the various

species of apes are distinguished from each other. Huxley gave an complete and authoritative reply to this question. The opposition still raised on many sides to absolutely without foundation. On the ground of careful comparative-anatomical research, Huxley proved that in all morphological respects the differences between the highest and lowest apes are greater than the corresponding differences between the highest ape and man. If the natural Liard's order of the Primates (excluding the bats), and divided it into three sub-orders, the first composed of the half-apes (*Lemnidae*), the second of the true apes (*Simidae*), the third of man (*Anthropidae*).

But, as we wish to pressed upon more strongly and importantly on the laws of systematic logic, we may, as the strength of Huxley's own law, go a good deal further in this division. We are justified in going at least one important step further, and assigning man his natural place outside one of the sections of the order of apes. All the features that characterize this group of apes are found in man, and are found in the other apes. We do not seem to be justified, therefore, in finding for man a special order distinct from the apes.

The order of the true apes (*Simidae* or *Primates*)—excluding the humans—has long been divided into two principal groups, which also differ in their geographical distribution. One group (*Platyrrhini*, or *new-world apes*) live in America. The other group, to which man belongs, are the *Catarrhini* or *old-world apes*; they are found in Asia and Africa, and were formerly in Europe. All the modern apes agree with man in the features that are chiefly used in zoological classification to distinguish between the two groups, especially in the dentition. This objection might be raised that the teeth are too subordinate an organ physiologically for us to lay stress on them in an important question. But there is a good reason for it; it is with perfect justice that zoologists have for more than a century paid particular attention to the teeth in the systematic division and arrangement of the orders of mammals. The number, form, and arrangement of the teeth are much more richly inherited in the various orders than most other characters.

Hence the line of division in man is very important. In the fully developed

condition we have thirty-two teeth; of these eight are incisors, four canines, and twenty molars. The eight incisors, in the middle of the jaws, have certain

Next to these, at each side of both jaws, is a canine (or "eye tooth"), which is larger than the incisors. Sometimes it is very prominent in man, as it is in most

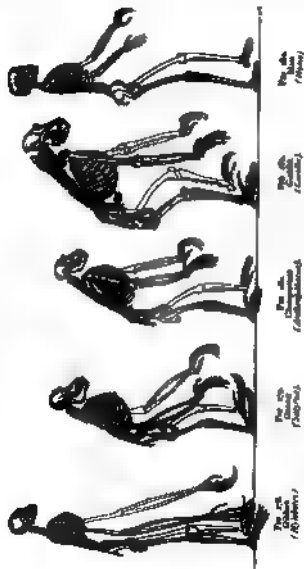


Fig. 96-100—Specimens of a man (Fig. 96) and the four apes (Fig. 97-100) from the same series. Fig. 96-100: Fig. 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000.

characteristic difference above and below. In the upper jaw the lower incisors are larger than the outer; in the lower jaw the inner are the smaller.

apes and many of the other mammals, and forms a sort of task. Next to this there are five molars above and below on each side, the first two of which (the

"prominent") one usually have only one root, and are included in the category of *bulli*; the three back ones are much longer, have two roots, and only one with the second tooth. The apex of the Old World, or all the living or fossil apes of Asia, Africa, and Europe, have the same dentition as man.

On the other hand, all the American apes have an additional promoter in each half of the jaw. They have six incisors above and below on each side, or thirty-two teeth altogether. This distinctive difference between the eastern and western apes has been on so frequently observed that it is very instructive for us. It is true that there seems to be an exception in the apex of a small variety of South American apes. The small shag apes (*Ateles* or *Leptodes*), which include the *torus* (*Blas*) and the *brachycephalus* (*Leptodes*), have only five incisors in each half of the jaw (instead of six), and as seen in its position in the eastern apes. But it is found, on closer examination, that they have three promoters, like all the eastern apes, and thus only the last variety has been lost. Hence the apparent exception really confirms the basic distinction.

Of the other features in which the two groups of apes differ, the structure of the snout is particularly instructive and conspicuous. All the eastern apes have the same type of snout as man—an comparatively narrow partition through the two halves, so that the nostrils can demonstrate. In some of them the same protrudes as far as the nose, and has the same characteristic structure. We have already alluded to the curious beak-shaped apes, which have a long, fleshy, curved snout. Most of the western apes have it in form, rather flat snout, like, for instance, the white-faced monkey (Fig. 104); but the nasal partition is thin and narrow in them all. The American apes have a different type of snout. The partition is very broad and thick at the bottom, and the wings of the nostrils are not developed, so that they point forwards instead of downwards. This difference in the form of the snout is so consistently observed in both groups that the apes of the New World are called "the snout" (*Platyrrhini*), and those of the Old World "curved-snout" (*Catarrhini*). The heavy margins of the ear (in the bottom of which is the tympanum) is short and wide in all the *Platyrrhini*,

but long and narrow in all the *Catarrhini*; and in man this difference also is significant.

This division of the apes into *Platyrrhini* and *Catarrhini*, on the ground of the above hypothetical features, is now generally admitted in zoology, and receives strong support from the geographical distribution of the two groups in the east and west. It follows at once, so regards the phylogeny of the apes, that two divergent lines proceeded from the common stem-form of the apes-order in the early Tertiary period, one of which spread over the Old, the other over the New, World. It is certain that all the *Platyrrhini* came of one stock, and also all the *Catarrhini*; but the former are phylogenetically older, and must be regarded as the stem-group of the latter.

What was the distance from this point of divergence to our own progeny? Man has lost the same characters, the same form of dentition, auditory passages, and eyes, as all the *Catarrhini*; in this it radically differs from the *Platyrrhini*. We are thus bound to regard him a pariah among the eastern apes in the order of Primates, or at least place him alongside of them. But it follows that man is a direct blood relative of the apes of the Old World, and can be traced to a common ancestor together with all the *Catarrhini*. In his whole organization and in his origin man is a true *Catarrhinus*. He originated in the Old World from an unknown eastern group of the eastern apes. The apes of the New World, or the *Platyrrhini*, form a divergent branch of our genealogical tree, and this is not directly related to the rest of the human race. We must assume, of course, that the earliest Eastern apes had the full dentition of the *Platyrrhini*. Hence we may regard this stem-group as a special stage (the twenty-sixth) in our ancestry, and deduce from it the twenty-seventh stage (the earliest *Catarrhinus*).

We have now reduced the whole of our current relation to the small and comparatively cruddy group that is represented by the sub-order of the *Catarrhini*, and we are in a position to answer the question of man's place in this sub-order, and say whether we are distant anything further from this position as to our immediate ancestry. In answering this question the comparison and able studies that Manley gives of

the comparative anatomy of man and the various *Catarrhini* in his *Atlas of Man and Monkeys* is of great assistance to us. It is quite clear from them that the differences between man and the highest *Catarrhini* (gorilla, chimpanzee, and orang) are in every respect slighter than the corresponding differences between the highest and the lowest *Catarrhini* (furthermost monkey, marmoset, baboon, etc.). In fact, within the small group of the tail-less or brachycephalic the differences between the various groups are not less than the differences between them and man. This is seen by a glance at the skeleton that Huxley has put together (Fig. 271-282). Whether we take the skull or the vertebral column or the ribs or the fore or hind limbs, or whether we consider the comparative of the mandible, lower-jaw, teeth, pharynx, etc., we always reach the same result: an impartial examination of this stage in our series differs from the other *Catarrhini* than the extreme forms of them (for instance, the gorilla and baboon) differ from each other. We may now, therefore, complete the Huxleyian list we have already quoted with the following phrase: "Whether in system of support we take, a comparison of their modifications in the series of *Catarrhini* always leads to the same conclusion: the supposed differences that separate man from the most advanced *Catarrhini* (among gorilla, chimpanzee) are not as great as those that separate this latter from the lowest *Catarrhini* (furthermost monkey, marmoset, baboon)."

We must, therefore, consider the descent of man from other *Catarrhini* to be fully proved. Whatever further information on the comparative anatomy and osteology of the living *Catarrhini* we may obtain in the future, it cannot possibly disturb this conclusion. Naturally, our *Catarrhini* structure must have passed through a long series of different forms before the human type was produced. The chief unknown fact affected this "series of man," or his differentiation from the nearest related *Catarrhini*, was the adaptation of the ear to posture and the development greater differentiation of the fore and hind limbs, the evolution of articulate speech and the organ, the larynx, and the further development of the brain and its functions, the end; natural selection had a great influence in this, as Darwin showed in his famous work.

With an eye to these problems we may distinguish at least four important stages in our *Catarrhini* ancestry, which represent pronounced stages in the historical process of the making of man. We may take, after the Lemnars the earliest and lowest *Platyrrhini* of South America, with *Ororhina* next, as the very-early stage of our genealogy; they were developed from the Lemnars by a peculiar modification of the brain, teeth, nose, and fingers. From these Lemnars man-apes were formed, the earliest *Catarrhini* or man-ape, with the human dentition (Huxley 1863, working by comparison of the teeth, lengthening of the body, reduction of the ear, and the loss of hair pro-motions). These oldest man-forms of the whole *Catarrhini* group were still closely related with man, and had long to go in being (*Cynopithecus*) or tailed-ape (*Ateles*, Fig. 273). They lived during the Tertiary period, and are found fossilized in the Miocene. Of the animal groups that perhaps the nearest to them are the *Hominoidea*.

If we take these *Hominoidea* as the early-man-ape stage in our ancestry, we may put next to them, as the intermediate, the tail-less anthropoid apes. This stage is given to the most advanced and man-like of the existing *Catarrhini*. They were developed from the other *Catarrhini* by losing the tail and part of the hair, and by a higher development of the brain, which forced its pressure in the continuous growth of the skull. Of this remarkable family there are only a few groups to-day, and we have already dealt with them (Chapter XV.)—the gibbons (*Hylodactylus*, Fig. 283) and orang (*Pongo*, Fig. 284, 285) in South-Eastern Asia and the Aethiopiens; and the chimpanzee (*Calypithecus*, Fig. 286, 287) and gorilla (*Gorilla*, Fig. 288) in Equatorial Africa.

The great interest that every thoughtful man takes in these recent animals of ours has found expression recently in a fairly large literature. The most distinguished of these works for popular treatment of the question of affinity is Robert Martens's little work on *The Anthropoid Ape*. Martens divides the present order into two families: (1) *Prosimii* (man and the anthropoid apes), and (2) *Semnopithecii*, *Catarrhini* and *Platyrrhini*. Professor Koenig, of Halleberg, has advanced a different view in his interesting and richly illustrated work on *The Origin and Development of the Primates*.

fact. This is a substantial supplement to my *Anthropogeny*, in as far as it gives the chief results of modern research on the early history of man and chimpanzee. But when Klatech declares the descent of man from the apes to be "irrationally narrow-minded, and false," in the belief that we are thinking of some living species of apes, we must remind him that no competent scientist has ever held so narrow a view. All of us look naturally—in the sense of Lamarck and Darwin—to the original unity (admitted by Klatech) of the primate stem. This common descent of all the Primates (man, apes, and lemurs) from one primitive stem-form, from which the most far-reaching populations follow for the whole of anthropology and ethnology is admitted by Klatech.

Well as by myself and all other competent zoologists who accept the theory of evolution in general. He says explicitly (p. 172), "The three anthropoid apes—gorilla, chimpanzee, and orang—seem to be branches from a common root, and this was not far from that of the gibbon and man." That is to the main the opinion that I have maintained (especially against Virchow) in a number of works ever since 1882. The hypothetical common ancestor of all the Primates, which must have lived in the earliest Tertiary period (more probably in the Cretaceous), was called by me *Archiprimate*; Klatech now calls it *Prosimia*. Dubois has proposed the private name of *Prohylobates* in continuation and much younger stem—the anthropomorphine (man and the anthropoids).

Three species. Name of these can be said to be absolutely the most man-like. The gorilla comes next to man in the structure of the hand and foot, the chimpanzee to the chief features of the skull, the orang in brain development, and the gibbon in the formation of the chest. None of these existing anthropoid apes is among the direct ancestors of our race. They are scattered survivors of an ancient branch of the Catarrhines, from which the human race developed in a particular direction.

Although man is directly connected with

this anthropoid family and originates from it, we may assign an important intermediate form between the *Prohylobates* and him (the twenty-ninth stage in our necessary), the ape-man (*Pithecanthropus*). I gave this name in the *History of Creation* to the "speechless primitive man" (*Athak*), which were man in the ordinary sense as far as the general structure is concerned (especially in the differentiation of the limbs), but lacked one of the chief human characteristics, articulate speech and the higher intelligence that goes with it, and so had a less developed brain. The phylogenetic hypothesis of the organization of this "ape-man" which I then advanced was brilliantly confirmed twenty-four years afterwards by the *Science Museum of the Great Britain*.

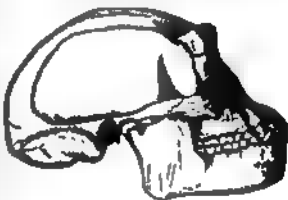


Fig. 25.—Skull of the third ape-man of Java (*Pithecanthropus erectus*), obtained by Eugene Dubois.

Pithecanthropus erectus by Eugene Dubois (then military surgeon in Java, afterwards professor at Amsterdam). In 1892 he found at Trinil, in the residency of Madioera in Java, in Pliocene deposits, certain remains of a large and very man-like ape (roof of the skull, femur, and teeth), which he described as "an exact ape-man" and a survivor of a "stem-form of man" (Fig. 25). Naturally, the *Pithecanthropus* excited the liveliest interest, on the long-sought transitional form between man and the ape: we needed to have found "the missing link." These were very interesting scientific discoveries of it at the last three International Congresses of Zoology (Leyden, 1895, Cambridge, 1898, and Berlin, 1901). I took an active part in the discussion at

Cambridge, and may refer the reader to the paper I read there on "The Present Position of Our Knowledge of the Origin of Man" (translated by Dr. Gadow with the title of *The Last Link*).

An extensive and valuable literature has grown up in the last ten years on the Pithecomthropus and the pliocene theory connected with it. A number of distinguished anthropologists, anatomists, paleontologists, and physiologists have taken part in the controversy, and made use of the important data furnished by the new series of prehistoric research. Hermann Kohnen has given a good summary of them, with many fine illustrations, in the above-mentioned work. I refer the reader to it as a valuable supplement to the present work, especially as I cannot go any further than into these anthropological and paleo-anthropological. I will only repeat that I think he is wrong in the attitude of hostility that he affects to take up with regard to my own view as the descent of man from the apes.

The most powerful exponent of the pliocene theory and the theory of evolution in general—during the last thirty years (until his death in September, 1900) was the famous Berlin anatomist, Rudolf Virchow. In the speeches which he delivered every year at various congresses and meetings on this question, he was never tired of asserting the "biological theory." His constant exclamation pliocene was: "It is quite certain that that bone was derived from the ape or any other animal." This has been repeated incessantly by opponents of the theory, especially theologians and pliocenists. In the language of speech that he delivered in 1895 at the anthropological Congress at Vienna, he said that "one might just as well have descended from a sheep or an elephant as from an ape." Adversary opponents like this only show that the human paleontologist, anatomist, who did so much for medicine in the establishment of modern pathology, and that the requisite anatomical or comparative anatomy and physiology, systematic anatomy and paleontology, he must judge even in the previous of anthropology. The Secondary anatomist, Gustav Hensel, deserves great praise for having the moral courage to oppose this dogmatic and ungrounded teaching of Virchow, and showing its unsoundness. The recent scientific works of Hensel's on the Pithecomthropus, the earliest man

of man, and the Neanderthal skull (offspring) will supply my readers and judges with the empirical material with which he can convince himself of the soundness of the erroneous dogmas of Virchow and his devoted friends (J. Kohnen, J. Gadow, etc.).

As the Pithecomthropus walked erect, and his brain (judging from the capacity of his skull, etc.) was midway between the lowest man and the modern apes, we must assume that the next great step in the advance from the Pithecomthropus to man was the further development of human speech and reason.

Comparative philology has recently shown that human speech is polyphonic in origin; that we must distinguish several (probably many) different primitive tongues that were developed independently. The evolution of language also involves us (both from its structure, in the child and its phylogeny in the race) the human speech proper was only gradually developed after the rest of the body had assumed its characteristic form. It is probable that language was not evolved until after the dispersal of the various species and races of men, and this probably took place at the commencement of the Quaternary or Deiluvial period. The question whether or not it certainly came towards the end of the Tertiary period, during the Pliocene, fourth or fifth glacial period.

The third and last stage of our natural ancestry is the race or species that (Hensel), etc. was gradually evolved from the preceding stage by the advent of animal language into articulate human speech. As to the time and place of this real "evolution of man" we not only require scientific evidence. It was probably during the Tertiary period in the human race of the Old World, rather on the mainland in tropical Africa or Asia, or on an earlier continent (Laurelia—now sunk below the waves of the Indian Ocean) which stretched from East Africa (Madagascar, Arabia) to East Asia (Sunda Islands, Farther India). I have given fully in my *History of Creation* (1897, 1900) the weighty reasons for choosing the descent of man from the anthropoid apes, and show how we may suppose the spread of the human race from the "Prometheus" over the whole earth. I have also dealt fully with the relations of the various races and species of man to each other.

SYNOPSIS OF THE CHIEF SECTIONS OF OUR STEM-HISTORY

First stage: The Protists.

Man's ancestors are unicellular organisms, originally unenclosed Monera like the Chromacea, structureless green particles of plants; afterwards real nucleated cells (first plant-like *Paraphysa*, then the *Paludina*, then plantophagous *Paludosa*, then the *Amoeba*).

Second stage: The Rhizozoa.

Man's ancestors are round colonial organisms of Protoczoa, they consist of a close association of many heterogametic cells, and thus are individuals of the second order. They resemble the round cell-communities of the *Macrophysa* and *Volvox*, equivalent to the endogametic blastula before globules, the wall of which consists of a single layer of related cells (blastoderm).

Third stage: The Gastraea.

Man's ancestors are *Gastraea*, like the simplest of the actual Metazoa (*Physalia*, *Cyanea*, *Hydra*, *Planaria*, etc.). Their body consists merely of a primitive gut, the wall of which is made up of the two primary germinal layers.

Fourth stage: The Platyzoa.

Man's ancestors have substantially the organization of simple *Platyzoa* (at first like the *Cryptosiphia Platyzoa*, later like the *Rhabdocoela Turbellaria*). The two-layered bilateral-symmetrical body has only one gut-opening, and develops the first traces of a nervous system from the ectoderm in the middle line of the back (Fig. 299, 300).

Fifth stage: The Vermes.

Man's ancestors have substantially the organization of unarticulated *Vermes*, at first *Gastrotrocha* (*Schizydra*), afterwards *Planaria* (*Nemertina*, *Enoplozoa*). Four secondary germinal layers develop, two middle layers arising between the bounding layers (mesoderm). The dorsal ectoderm forms the vertebral plate, *Neurogänger* (Fig. 243).

Sixth stage: The Prochordoma.

Man's ancestors have substantially the organization of a simple unarticulated *Chordoma* (*Cephalopoda* and *Amphioxus*). The unsegmented chorda develops between the

dorsal notochordal tube and the ventral gut-tube. The simple color-pouches divide by a frontal septum into two on each side: the dorsal pouch (*operculum*) forms a tricuspid plate; the ventral pouch (*hypostoma*) forms a ground. Head-gut with gill-slits.

Seventh stage: The Asymetria.

Man's ancestors are skullless *Vertebrata*, like the *Amphioxus*. The body is a series of metameres, the lateral of the premaxillary segments are developed. The head contains on the ventral half the branchial gut, the trunk the hepatic gut. The notochordal tube is still simple. No skull, jaws, or limbs.

Eighth stage: The Craniota.

Man's ancestors are jawless *Craniota* (like the *Myxinoidea* and *Petromyzontia*). The number of metameres increases. The fore-end of the notochordal tube expands into a capsule and forms the brain, which soon divides into five cerebral vesicles. In the sides of it appear the three higher sense-organs: ears, eyes, and sensory tentacles. No jaws, limbs, or bounding bladder.

Ninth stage: The Ichthyota.

Man's ancestors are fish-like *Craniota*: (1) *Uraniozoa* fishes (*Selachii*), (2) plated fishes (*Gnathostomi*), (3) amphibious fishes (*Dipnozoa*), (4) scaled amphibians (*Stegocephala*). The ancestors of this series develop two pairs of limbs: a pair of fore (breast-fins) and of hind (belly-fins) legs. The gill-arches are formed between the gill-slits: the first pair forms the notochordal arches (upper and lower jaws). The bounding bladder (heart) and pancreas grow out of the gut.

Tenth stage: The Amphibia.

Man's ancestors are *Amphibia* or gill-less *Vertebrata*: (1) *Primitiva Amphibia* (*Protobranchia*), (2) *Stenocraniota*, (3) *Primitiva Mammalia* (*Mammalia*), (4) *Macropoda*, (5) *Leucon* (*Primate*), (6) *Western apes* (*Platyrrhini*), (7) *Eastern apes* (*Catarrhini*): at first tailed *Cynopithecus*, then tail-less *Anthropoids*; later speechless *ape-men* (*Aloids*). Finally speaking man. The ancestors of these *Amphibia* develop an amnion and allantois, and gradually assume the mammal, and finally the specifically human, form.

CHAPTER XXIV.

EVOLUTION OF THE NERVOUS SYSTEM

THE previous chapters have taught us how the human body as a whole develops from the first simple rudiment, a single layer of cells. The whole human race owes its origin, like the individual man, to a single cell. The unicellular stem-form of the race is reproduced daily in the unicellular embryonic stage of the individual. We have now to consider in detail the evolution of the various parts that make up the human frame. I cannot, naturally, confine myself to the most general and principal outlines, to make a special study of the evolution of each organ and tissue is both beyond the scope of this work, and probably beyond the historic capacity of most of my readers to appreciate. In tracing the evolution of the various organs we shall follow the method that two illustrious guides, an exception that we shall now have to consider the ontogeny and phylogeny of the organs together. We have seen, in studying the evolution of the body as a whole, that phylogeny casts a light over the darker paths of ontogeny, and that we should be almost unable to find our way in it without the aid of the former. We shall have the same experience in the study of the organs in detail, and I shall be compelled to give simultaneously their ontogenetic and phylogenetic origin. The more we go into the details of organic development, and the more closely we follow the rise of the various parts, the more we see the inseparable connection of embryology and stem-history. The ontogeny of the organs can only be understood in the light of their phylogeny, just as we found of the embryology of the whole body. Each embryonic form is determined by a corresponding stem-form. This is true of details as well as of the whole.

We will consider first the animal and then the vegetative systems of organs of the body. The first group consists of the psychic and the motor apparatus. To the former belong the skin, the nervous system, and the sense-organs. The motor apparatus is composed of the

passive and the active organs of movement (the skeleton and the muscles). The second or vegetative group consists of the nutritive and the reproductive apparatus. To the nutritive apparatus belong the elementary canal with all its appendages, the vascular system, and the renal (kidney) system. The reproductive apparatus comprises the different organs of sex (embryonic glands, sexual ducts, and copulatory organs).

As we know from previous chapters (XI.-XIII.), the animal systems of organs (the organs of sensation and locomotion) develop for the most part out of the outer primary germ-layer, or the ectodermis (skin) layer. On the other hand, the vegetative systems of organs arise for the most part from the inner primary germ-layer, the visceral layer. It is true that the ontogeny of the animal and vegetative spheres of the body in man and all the higher animals is by no means rigid; several parts of the animal apparatus (for instance, the greater part of the muscles) are formed from cells that come originally from the ectoderm; and a great part of the vegetative apparatus (for instance, the mouth-cavity and the gonoducts) are composed of cells that come from the ectoderm.

In the more advanced animal body there is so much interlacing and displacement of the various parts that it is often very difficult to indicate the sources of them. But, broadly speaking, we may take it as a positive and important fact that in man and the higher animals the chief part of the animal organs comes from the ectoderm, and the greater part of the vegetative organs from the endoderm. It was for this reason that Carl Erism von Baer called the one the animal and the other the vegetative layer (see p. vii).

The solid foundation of this important class is the gastrula, the most instructive embryonic form in the animal world, which we still find in the same shape in the most diverse classes of animals. This form points demonstrably to a

cases the simple cell-layer of the ectoderm is at once skin, locomotive apparatus, and nervous system.

When we come to the higher Metazoa, in which the sensory functions and their organs are more advanced, we find a division of labour among the ectodermal cells. Groups of sensitive nerve cells separate from the ordinary epidermal cells; they retain a protected

the remainder form special neural ganglia there. Even in the Platyhelms, especially the *Planorbidae*, we find an independent nervous system.

This is the "upper pharyngeal ganglion," or *acropharynx*, situated above the gullet (Fig. 241 p.). From this rudimentary structure has been developed the elaborate central nervous system of the higher

In some of the earth-worms, the first rudimentary central nervous system



FIG. 241.—Ectodermal cells of a human embryo at two months. (From Müller.)

(Fig. 74 a) is a local thickening of the skin-nerve layer (*he*), which afterwards separates altogether from the horny plate. In the earliest Platyhelms (*Cryptosporus*) and *Vermatans* (*Gastropoda*) the acropharynx remains in the epidermis. But the medullary tube of the Vertebrates originates in the same way. Our embryology has taught us that this first structure of the central nervous system also develops originally from the outer germinal layer.

Let us now examine more closely the evolution of the human skin, with its various appendages, the hairs and glands. The external covering has, physiologically, a double and important part to play. It is, in the first place, the common integument that covers the whole surface of the body, and forms a protective — layer for the other organs. As such it also effects a certain exchange

either between the body and the outside atmosphere (exhalation, perspiration). In the second place, it is the

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of bodies that

The human skin (like that of all the higher animals) is composed of two layers — the epidermis and the dermis.

The outer skin, or epidermis, is a simple ectodermal cells, and contains no blood-vessels (Fig. 284 a, b). It developed

two layers. The underlying skin (or dermis) consists chiefly of a

outermost partial stratum of the middle germ-layer, as the dermis layer. The corium is much thicker than the epidermis. In its deeper strata (the subcutis) there are clusters of fat-cells (Fig. 284 d). Its uppermost stratum (the corium proper, or the papillary stratum) forms, over almost the whole surface of the body, a number of conical microscopic papillae (resembling like earth), which push into the overlying epidermis (e). These tactile or sensory papillae contain the first sensory organs of the skin, the touch corpuscles. Others contain coiled end-loops of the blood-vessels that penetrate the skin (f, g). The various parts of the corium arise by division of labour from the originally homogeneous cells of the cuti-plate, the outermost lamina of the mesodermic skin-fibre layer (Fig. 285 A, B, C).

In the same way, all the parts and appendages of the epidermis develop by differentiation from the homogeneous cells of this horny plate (Fig. 285). At an early stage the simple cellular layer of this horny plate divides into two. The inner and outer stratum (Fig. 284 b) is known as the mucous stratum, the outer and harder (c) as the horny (corneous) stratum. This horny layer is being constantly used up and rubbed away at the surface; new layers of cells grow up in their place out of the underlying mucous stratum. At first the epidermis is a simple covering of the surface of the body. Afterwards various appendages "evolve" from it, some internally, others externally. The external appendages are the cutaneous glands — sweat, fat, etc.

The external appendages are the hairs and nails.

The cutaneous glands are originally merely solid cone-shaped growths of the epidermis, which sink into the underlying corium (Fig. 286 1). Afterwards a canal (2, 3) is formed inside them, either by

is or by the secretion of fluid

Some of the glands, as the sudoriferous, do not ramify (Fig. 286 4). These glands, which secrete perspiration, are very long, and have spiral coil at the end, but they never ramify, so also the sebaceous glands of the mammals. The glands give out buds and ramify; thus, for instance, the lachrymal glands of the upper eyelid that secrete tears (Fig. 286 5), and the sebaceous glands which secrete the fat in the skin and generally open into the hair-follicles. Sudoriferous and sebaceous glands are found only in mammals. But we find lachrymal glands in all the three classes of Arthropods—reptiles, birds, and mammals. They are wanting in the lower aquatic vertebrates.

The mammary glands (Figs. 287 and

288) secrete the milk for the feeding of the new-born mammal. In some of their unusual uses, these structures are nothing more than large sebaceous glands in the skin. The milk is formed by the liquefaction of the fatty milk-cells inside the branching mammary-gland tubes (Fig. 287 1), in the same way as the keratinous or hair-fat, by the solution of fatty cells inside the sebaceous glands. The outline of the mammary glands enlarges and forms sac-like mammary ducts (2), these narrow again (3), and open in the teats or nipples of the breast by isthmus to

The first gland is epidermal, sebaceous and

lobes (Fig. 288). These gradually ramify,

the lobes. Thus is formed the prominent female breast (*mamma*), on the top of which rises the teat or nipple (*mamilla*). The latter is only developed later on, when the mammary gland is fully formed, and this ontogenetic phenomenon is very interesting, because

mammals (like stem-forms of the whole leaf) have no teats. In them the milk comes out through a flat portion of the ventral skin that is pierced like a sieve. In we still find in the lowest living mammals— *Marsupial Monotremes* —of Australia. The young animal licks the

In many of the lower mammals we find a number of milk-glands at different parts of the ventral surface. In the human female there is usually only a pair of glands, at the breast; and it the same with the apes, bats, elephants, and several other mammals. Some

of them have successive pairs of



The old-primordial mammary glands from a human embryo of four months. (From A. B. 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glands (or even more) female. Some species of breasts, like pigs and hedgehogs (Fig. 289). This polymorphism points back to an older stem-form. We often find

(Fig. 289 2) Sometimes, moreover, the animal mammary glands are fully developed and can suckle in the male, but

organs without function in the male. We have already (Chapter XI) dealt with this remarkable and interesting instance of atavism.

While the cutaneous glands are inner growths of the epidermis, the appendages

which we call hairs and quills are extended local growths in it. The scale (*Figures 1*)

which we

ally

instead of them; the ungulate. The stem-form of the mammalia had claws; we find them in a rudimentary form even in the salamander. The horny claws are highly developed in most of the reptiles (*Fig. 264, p. 245*), and the mammals have inherited them from the earliest representatives of this class, the marsupials (*Tasmanian*). Like the hoof-



Fig. 264.—The female butterfly (*Vanessa io*) is a common example of a butterfly which opens also the wings. (*From H. Hoyer*.)

(*ungulate*) of the Ungulates the walls of lips and men have been cut off from the claws of the older mammals. In the human embryo the first rudiment of the nail is found (between the horny and the mucous stratum of the epidermis) in the fourth month. But their edges do not penetrate through until the end of the sixth month.

The most interesting and important appendages of the epidermis are the hairs; on account of their peculiar composition and origin we must regard them as highly characteristic of the whole mammalian class. It is true that we also find hairs in many of the lower animals,

like the hairs of plants, are thread-like appendages of the surface, and differ entirely from the hairs of the mammals in the details of their structure and develop-

Micrology of the hair

views as to their phylogeny. On the older view the hairs of the mammals are equivalent or homologous to the feathers of the bird or the horny scales of the reptile. As we deduce all these classes of Animals from a common stem-group, we must assume that these Peruvian stem-reptiles had a complete scaly coat, inherited from their Carboniferous ancestors, the scaled amphibian (*Synbranchia*), the horny scales of their corium were covered with horny scales. In passing from aquatic to terrestrial life the horny scales were further developed, and the horny scales degenerated in most of the reptiles. As regards the bird's feathers, it is certain that they are modifications of the horny scales of their reptilian ancestors. But it is otherwise with the hairs of the mammals. In their case the

has lately been advanced on the basis of very extensive research, by Friedrich Meunier, that they evolved from the cutaneous

non-organs of amphibian ancestors by modification of functions; the epidermal structure is very similar in both in its embryonic rudiments. This modern view, which had the support of the greatest expert on the vertebrates, Carl Gegenbaur, can be harmonized with the older theory to an extent, in the sense that both

of buds and hairs, were very closely connected originally. Probably the budding of the skin-nerve in the pander the protection of the

each subsequently by the cornification of the hairs; many hairs are still sensory organs (tactile hairs on the muzzle and claws of many mammals; pubic hairs).

The middle position of the genetic connection of scales and hairs was advanced in my *Systematic Phylogeny of the Vertebrates* (p. 433). It is confirmed by the similar arrangement of the two cutaneous formations. As Meunier pointed out, the hairs, as well as the cutaneous non-organs and the scales, are at first arranged in regular longitudinal series, and they afterwards break into alternate groups. In the embryo of a bear two

inches long, which I owe to the kindness of Herr von Schmerzbirg (of Arva Varalla, Hungary), the back is covered with sixteen to twenty alternating longitudinal rows of aculei protuberances (Fig. 56g). They are at the same time arranged in regular transverse rows, which converge at an acute angle from both sides towards the middle of the back. The tip of the scale-like wart is turned inwards. Between these larger hood scales (or groups of hairs) we find numbers of rudimentary smaller hairs.

The human embryo is, as a rule, entirely clothed with a thick coat of fine silky hair known as lanugo. During the last three or four weeks of gestation this embryonic woolly coat (lanugo) generally disappears in part during the last weeks of fetal life. But in any case, at its birth, it is still present

on the back, and is replaced by the finer coat of the post-natal hair. These permanent hairs are out of the follicles, which are given off from the epidermis of the developing woolly skin. The embryonic woolly coat is woolly in the case of the human embryo, covers the whole body, with the exception of the palms of the hands and soles of the feet.

It is always born, as in the case of apes and of most other mammals, sometimes the woolly coat of the embryo has a striking effect, by its colour, on the later permanent furrows. Hence it happens occasionally, for instance, among our Indo-Germanic races, that children of blond parents are born with a dark brown or even a black woolly coat. Not until this has disappeared do we see the permanent blond hair which the child has inherited. Sometimes the darker coat remains for a while, and even months, after birth. This remarkable woolly coat of the latest embryo is a legacy from the apes, our ancient long-tailed ancestors.

It is not less noteworthy that many of the higher apes approach man in the thickness of the hair on various parts of the body. With most of the apes, especially the higher Catarrhines (or narrow-nosed apes), the face is mostly, or entirely, hair, or at least it has hair no longer so thick than that of man. In these cases, too, the thick of the hair is usually provided with a thicker growth of hair; this is lacking, however, in the case of the bald-headed chimpanzee (*Ursus* *calvus*). The number of many species of apes have a considerable beard on the

cheeks and chin; this sign of the mammalian sex has been acquired by sexual selection. Many species of apes have a very thin covering of hair on the breast and the upper side of the limbs—much thinner than on the back or the under side of the limbs. On the other hand, we are often astonished to find tufts of hair on the shoulders, back, and extremities of members of our Indo-Germanic and of the Semitic races. Exceptional hair on the face, as on the whole body, is hereditary in certain families of hairy men. The quantity and the quality of the hair on head and chin are also conspicuously transmitted in families. The extraordinary variations in the total or partial hairy coat of the body, which is so noticeable, not only in comparison



Fig. 56. Newborn child of a newborn child. A small central gland is visible on the chin (from Langley).

different races of men, but also in comparing different families of the same race, can only be explained on the assumption that in man the hairy coat is, on the whole, a rudimentary organ, a useless inheritance from the more thickly-coated apes. In this man resembles the elephant, rhinoceros, hippopotamus, whale, and other mammals of various orders, which have also, almost entirely or for the most part, lost their hairy coat by adaptation.

The particular process of adaptation by which man lost the growth of hair on most parts of his body, and retained it augmented it at some points, was most probably sexual selection. As Darwin has recently shown in his *Descent of Man*, sexual selection has been very active

in this respect. As the male anthropoid apes choose the females with the least hair, and the females favoured the males with the finest growths on chin and head, the general coating of the body gradually degenerated, and the hair of the head and hand was more strongly developed. The growth of hair at other parts of the body (armpit, pubic region) was also probably due to sexual selection. Moreover, changes of climate, or habits, and other adaptations unknown to us, may

held apes—gorilla, chimpanzee, orang, and several species of gibbons—besides man (Figs. 203, 207). In other species of gibbons the hair is pointed towards the hand both in the upper and lower arm, as in the rest of the mammals. We can easily explain this remarkable peculiarity of the anthropoids and man on the theory that our common ancestors were accustomed (as the anthropoid apes are to-day) to place their hands over their heads, or across a branch above their



FIG. 203.—Underside of a baboon (*Ursus arvensis*). A man from ventral side, B from the left.

have resisted the disappearance of the hairy coat.

The fact that our coat of hair is inherited directly from the anthropoid apes is proved in an interesting way, according to Darwin, by the direction of the rudimentary hairs on our arms, which cannot be explained in any other way. Both on the upper and the lower part of the arm they point towards the elbow. Here they meet at an obtuse angle. This curious arrangement is found only in all anthro-

poids, during cunn. In this position, the fact that the hairs point downwards helps the rain to run off. Thus the direction of the hair on the lower part of our arm reminds us to-day of that useful custom of our anthropoid ancestors.

The nervous system in man and all the other Vertebrates is, when fully formed, an extremely complex apparatus, that we may compare, in anatomic structure and physiological function, with an extensive telegraphic system. The chief station of

the system is the central marrow or central nervous system, the innumerable ganglionic cells or neurons, all of which are connected by branching processes with each other and with numerous of very fine conducting wires. The latter are the peripheral and ubiquitous nerve-fibres; with their terminal apparatuses, the sense-organs, etc., they constitute the conducting marrow or peripheral nervous system. Some of them—the sensory nerve-fibres—conduct the impressions from the skin and other sense-organs to the central marrow; others—the motor nerve-fibres—convey the commands of the will to the muscles.

The central nervous system or central marrow (*medulla centralis*) is the real organ of psychic action in the narrower sense. However we conceive the intimate connection of this organ and its functions,

which we call sensation, we are inseparably dependent on the development of the one man and all the higher

gives us most important information regarding the nature of the " soul," it should be full of interest. If the central marrow develops in just the same way in the human embryo as in the embryo of the other mammals, the evolution of the human psychic organ from the central

(them from the lower vertebrates, must be beyond question. No one can doubt the enormous bearing of these embryonic phenomena.

In order to understand them fully we let first say a word or two of the general and the anatomic comparison of the (the human central marrow like the central nervous system of all other Craniotes, it consists of two parts, the head-marrow or brain (*medulla capitis* or *encephalon*) and the spinal-marrow (*medulla spinalis* or *neuraxon*). The one is enclosed in the bony skull, the other in the bony vertebral column. Twelve pairs of cerebral nerves proceed from the brain.

spinal nerves
root of the body (Fig. 375). On anatomic investigation the spinal
found to be a cylindrical cord,
both in the region
(at the base
vertebra) and the region of the base (at

the first lumbar vertebra) below (Fig. 371). At the cervical half the strong nerves of the upper limbs, and at the lumbar half those of the lower limbs, proceed from the spinal cord. Above, the latter passes into the brain through the medulla oblongata (Fig. 391, 392). The spinal cord seems to be a thick mass of nervous matter, but it has a narrow canal at its axis, which passes into the further



Fig. 391.

Fig. 392.

Fig. 391.—Human embryo, the central nervous system, black. (From Kollmer, *Die Entwicklung des menschlichen Embryos*, 1891, p. 100.)
Fig. 392.—Human embryo, the central nervous system, black. (From Kollmer, *Die Entwicklung des menschlichen Embryos*, 1891, p. 100.)

Fig. 392.—Central marrow of a human embryo, black. (From Kollmer, *Die Entwicklung des menschlichen Embryos*, 1891, p. 100.)
Fig. 393.—Human embryo, the central nervous system, black. (From Kollmer, *Die Entwicklung des menschlichen Embryos*, 1891, p. 100.)

cerebral ventricles above, and is filled, like these, with a clear fluid.

The brain is a large, complex structure. On general examination it divides into two parts, the cerebrum and cerebellum. The cerebrum lies in front and above, and has the familiar characteristic convolutions and furrows on its surface (Figs. 392, 393). The upper side it is divided by a deep longitudinal fissure into two halves,

cerebral hemispheres; these are connected by the corpus callosum. The larger cerebrum is separated from the small cerebellum by a deep transverse furrow. The latter lies behind and below, and has also numbers of furrows, but much less and more regular, with convolutions between, at its surface. The cerebellum also is divided by a longitudinal fissure into two halves, the "small hemispheres." These are connected by a narrow-shaped plate, the verger cerebelli, which, and by the broad base of each lobe (Fig. 295, 17, 18).

But comparatively unknown and unknown work we find in man and all the other

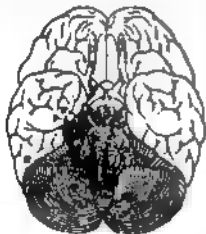


FIG. 295.—The human brain, seen from above (Fig. 1, page 1). Above, in front, is the cerebrum, with its deep longitudinal furrow, the transverse furrow, and the cerebellum. The cerebellum is seen from below, showing its deep longitudinal furrow, the verger cerebelli, and the broad base of each lobe.

Compared the brain is as first conceived, but of these two, but of these, and afterwards five, consecutive parts. There are found in just the same form—as five consecutive units—in the embryo of all the Crustacea, from the C. clausus and T. clausus to man. But, however much they agree in their rudimentary condition, they differ considerably afterwards. In man and the higher mammals the first of these ventricles, the cerebrum, grows so much that in its mature condition it is by far the largest and heaviest part of the brain. To it belong not only the large hemispheres, but also the corpus callosum that unites them, the olfactory lobes,

from which the olfactory nerves start, and most of the structures that are found at the roof and bottom of the large lateral ventricles inside the two hemispheres, such as the corpus callosum. On the other hand, the optic chiasm, which lies between the latter, belongs to the second division, which develops from the "intermediate brain", so the same section being the single third cerebral ventricle and the structures that are known as the corpus callosum, the infundibulum, and the pons. Behind these parts we find, between the cerebrum and cerebellum, a small ganglion composed of two parts, which is called the corpus quadrigemum as a result of a superficial transverse section cutting across (Figs. 295, 296, 297, 298). Although the quadrigemum is very long and narrow in man and the higher mammals, it forms a special third section, greatly developed in the lower vertebrates, the "midbrain." The fourth section is the "hindbrain" or (with great accuracy) to the narrower part, with the single smaller part. The cerebellum and the pair of lateral parts, the "small hemispheres" (Fig. 295, 17, 18). Finally, we have the fifth and last section, the cerebellum (Fig. 295, 17, 18), which contains the single fourth cerebral ventricle and the cerebellar parts (pyramidal, olivary bodies, corpus cerebelli). The cerebellum, therefore, passes straight into the cerebellar ventricle (small ventricle). The cerebellar ventricle of the spinal cord and cerebellum share with the quadrigemum fourth ventricle in the middle of the cerebellum, the base of which is the quadrigemum depression. From here a narrow duct, called "the aqueduct of Sylvius," passes through the corpus quadrigemum to the third cerebral ventricle, which lies between the two optic thalami, and this in turn is connected with the pair of lateral ventricles, each of which is the right and left in the large hemispheres. Thus all the cavities of the cerebral ventricles are directly interconnected. All these parts of the brain have an infinitely complex structure in detail, but we cannot go into this. Although it is much more complicated in man and the higher Vertebrates than in the lower classes, it develops in them all from the same rudimentary structure, the five simple cerebral ventricles of the embryonic brain.

Now before we consider the development of the complicated structure of the brain from this simple series of ventricles, let

us glance for a moment at the lower unicells, which have no brain. Even in the skull-less vertebrate, the Annelid, we find no independent brain, as we have seen. The whole central nervous system is merely a simple cylindrical cord which runs the length of the body, and ends equally simply at both extremities—a plain medullary tube. All that we can discover is a small vesicular hump at the forward part of the tube, a degenerate rudiment of a primitive brain. We meet the same simple medullary tube in the first structure of the ascidian larva, in its same characteristic position, above the chords. On closer examination we find here also a small vesicular swelling

at the forward end of the tube, the first trace of a differentiation of it into brain and spinal cord. It is probable that this differentiation was more advanced in the extinct Pterobranchs, and the brain was more pronounced (Figs. 114-120). The brain is phylogenetically older than the spinal cord, as the trunk was not developed until after the head. If we consider the undulating affinity of the head to the Vermis, and remember that we can trace all the Chordonia to lower Vermis, it seems probable that the simple central marrow of the former is equivalent to the simple nervous ganglion, which lies above the gut in the lower worms, and has long been known as the "upper pharyngeal ganglion" (*ganglion pharyngeum superior*); it would be better to call it the primitive or vertical brain (*acroganglion*).

Probably this upper pharyngeal ganglion of the lower worms is the structure from which the complex central marrow of the higher animals has been evolved. The medullary tube of the Chordonia has been formed by the lengthening of the vertical brain on the dorsal side. In all the other animals the central nervous system has been developed in a totally different way from the upper pharyngeal ganglion; in the Articulates, especially, a pharyngeal ring, with ventral marrow, has been added. The Molluscs also have a pharyngeal ring, but it is not found in the Vertebrates. In them the central

marrow has been prolonged down the dorsal side, in the Articulates down the ventral side. This fact proves of itself that there is no direct relationship between the Vertebrates and the Articulates. The underwriters attempt to derive the dorsal marrow of the former from the ventral marrow of the latter have totally failed (cf. p. 319).

When we examine the embryology of the human nervous system, we must start from the important fact, which we have already seen, that the first structure of it in man and all the higher Vertebrates is the simple medullary tube, and that this separates from the outer germinal layer in the middle line of the so-called

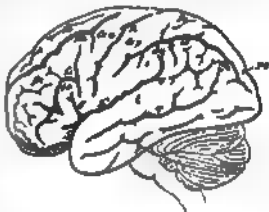


FIG. 121.—The human brain, seen from the left. (From H. Meyer.) The surface of the cerebrum is indicated by lines, and those of the cerebellum by dots. Under the latter we see the medulla oblongata. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000.

embryonic shield. As the reader will remember, the straight medullary furrow first appears in the middle of the shield-shaped embryonic shield. At each side of it the parallel borders curve over in the form of dorsal or medullary swellings. These bend together with their free borders, and then form the closed medullary tube (Figs. 133-137). At first this tube lies directly underneath the horny plate; but afterwards it unrolls forwards, the upper edges of the prevertebral plates joining together between the horny plate and the tube, joining above the latter, and forming a completely closed canal. As Gegenbaur very properly observes, "the gradual unfolding in the

lower part of the body is a process acquired with the progressive differentiation and the higher potentiality that this secures; by this process the region of greater value in the organism is buried within the frame" (Cf. Figs. 143-146).

In the *Cyclonema*—a stage above the *Acanthia*—the free end of the cylindrical medullary tube begins early to expand into a pear-shaped vesicle; this is the first outline of an independent brain. In this way the central nervous of the Vertebrates divides clearly into its two chief sections, brain and spinal cord. The simple vesicular form of the brain, which persists for some time in the *Cyclonema*, is found also at first in all the higher Vertebrates (Fig. 153, 160). But in these it soon passes away, the one vesicle being divided into several successive parts by transverse constrictions. There are first two of these constrictions,



FIG. 146. FIG. 147. FIG. 148.

FIG. 146-148.—Sectional anatomy of the brains of *Cyclonema* from the ventral end. 1, not long after hatching; 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 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1000.

dividing the brain into three successive vesicles (fore brain, middle brain, and hind brain, Fig. 154, 155, 156). Then the first and third are sub-divided by transverse constrictions, and thus we get five successive vesicles (Fig. 158).

In all the Crustacea, from the *Cyclonema* up to man, the same parts develop from these five original cerebral vesicles, though in very different ways. The first vesicle, the fore brain (Fig. 153, 154), forms by far the largest part of the cerebrum—namely, the large hemispheres, the olfactory lobes, the corpora semia, the callicorn, and the fornix. From the second vesicle, the intermediate brain (5), originates especially the optic thalami, the other parts that surround the third cerebral vesicle, and the infundibulum and pineal gland. The third vesicle, the middle brain (3), produces the sensory quadrigemina and

the segment of *Salpina*. From the fourth vesicle, the hind brain (4), develops the greater part of the cerebellum—namely, the vermis and the two small hemispheres. Finally, the fifth vesicle, the after brain (6), forms the medulla oblongata, with the quadrangular pit (the floor of the fourth ventricle), the pyramids, olivary bodies, etc.

We must certainly regard it as a comparatively anatomical and ontogenetic fact of the greatest significance that in all the Crustacea, from the lowest *Cyclonema* and *Salpina* up to the ape and man, the brain develops in just the same way in the embryo. The first rudiment of it is always a simple vesicular enlargement of the free end of the medullary tube. In every case, from three, then five, vesicles develop from this bulb, and the permanent brain with all its complex anatomic structures, of so great a variety in the various classes of Vertebrates, is formed from the five primitive vesicles. When we compare the various brain of a fish, an amphibian, a reptile, a bird, and a mammal, it seems incredible that we can trace the various parts of these organs, that differ so much internally and externally, to common types. Yet all these different Crustacean brains have started with the same rudimentary structure. To continue ourselves at this we have only to compare the corresponding stages of development of the embryos of these different animals.

The comparison is extremely instructive. If we traced it through the whole series of the Crustacea, we soon discover this interesting fact: In the *Cyclonema* (the *Hydromedusa* and *Planarian*), which we have recognized as the lowest and earliest Crustacea, the whole brain remains throughout life at a very low stage, which is very brief and passing in the embryos of the higher Crustacea; they retain the five original sections of the brain unchanged. In the fishes we find an essential and considerable modification of the five vesicles: It is clearly the brain of the *Salpina* in the first place, and subsequently the brain of the *Castella*, from which the brain of the rest of the fishes on the one hand and of the *Dipnoans* and *Amphibia*, and through those of the higher Vertebrates, on the other hand, must be derived. In the fishes and *Amphibia* (Fig. 150) there is a preponderant development of the middle brain, and also the after brain, the fore, second, and

the word "and." The highest achievements of the animal body—the wonderful manifestations of consciousness and the complex molecular processes of thought—have their seat in the fore brain. We can remove the large hemisphere, piece by

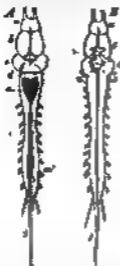


FIG. 30.—Brain and spinal cord of the frog. (From *Larousse*, *Il y en a pour tous*.) *a*, olfactory lobes; *b*, optic lobes; *c*, cerebellum; *d*, hind brain; *e*, midbrain; *f*, fore brain; *g*, spinal cord; *h*, spinal ganglia; *i*, spinal roots of the spinal cord. (From *Cyclopedia*.)



FIG. 31.—Brain of an alligator. (From *Larousse*, *Il y en a pour tous*.) *a*, optic lobes; *b*, olfactory lobes; *c*, cerebellum; *d*, hind brain; *e*, midbrain; *f*, fore brain; *g*, spinal cord; *h*, spinal ganglia; *i*, spinal roots of the spinal cord. (From *Cyclopedia*.)

piece, from the mammal without killing it, and we then see how the higher functions of consciousness, thought, will, and sensation, are gradually destroyed, and in the end completely extinguished. If the animal is fed artificially, it may be

kept alive for a long time, as the destruction of the psychic organs by no means involves the extinction of the faculties of digestion, respiration, circulation, urination—in a word, the vegetative functions. It is only conscious sensation, voluntary movement, thought, and the combination of various higher psychic functions that are affected.

The fore brain, the organ of those functions, only attains this high level of development in the more advanced Placental, and thus we have the simple explanation of the intellectual superiority of the higher mammals. The soul of most of the lower Placentals is not much above that of the reptiles, but among the higher Placentals we find an uninterrupted gradation of mental power up to the apes and man. In mammals with this we find an astonishing variation in the



FIG. 32.—Brain of a human embryo. (From *Larousse*, *Il y en a pour tous*.) *a*, olfactory lobes; *b*, optic lobes; *c*, cerebellum; *d*, hind brain; *e*, midbrain; *f*, fore brain; *g*, spinal cord; *h*, spinal ganglia; *i*, spinal roots of the spinal cord. (From *Cyclopedia*.)

degree of development of their fore brain not only quantitatively, but also qualitatively. The mass and weight of the brain are much greater in modern mammals, and the differentiation of its various parts more important, than in their extinct Tertiary ancestors. This can be shown paleontologically in any particular order. The brains of the living ungulates are (relatively to the size of the body) four to six times (in the highest groups even eight times) as large as those of their earlier Tertiary ancestors, the well-preserved skulls of which enable us to determine the size and weight of the brain.

In the lower mammals the surface of the cerebral hemisphere is quite smooth and level, as in the rabbit (Fig. 304). Moreover, the fore brain remains so small that it does not cover the middle lobe. At a stage higher the middle

brain is covered, but the hind brain remains free. Finally, in the ape and man, the latter also is covered by the fore brain. We can trace a similar gradual development in the fingers and convolu-

tions here discovered that this is not the case, but that the characteristic features of the human brain are found in a rudimentary form in the lower apes, and are more or less fully developed in the higher apes. Huxley has convincingly shown, in his *Man's Place in Nature* (1863), that the difference in the formation of the brain within the ape-group constitutes a deeper gulf between the lower and higher apes than between the higher apes and man.

The comparative anatomy and physiology of the brain of the higher and lower mammals are very instructive, and give important information in connection with the chief questions of psychology.

The central marrow (brain and spinal cord) develops from the medulla oblongata, and the same applies to the conducting masses of "peripheral nervous system." It contains the sensory nerves, which conduct centripetally the



FIG. 261.—Brain of a 14-day embryo. (From a drawing of the brain of a 14-day embryo, showing the forebrain, midbrain, and hindbrain, and the development of the cerebral hemispheres, cerebellum, and brainstem.)

tions that are found on the surface of the cerebrum of the higher mammals (Huxley, 1863). If we compare different groups of mammals in regard to these features and convolutions, we find that their development proceeds step by step with the advance of manifest life.

Of late years great attention has been paid to this special branch of cerebral anatomy, and very striking individual differences have been detected within the limits of the human race. In all human beings, of special gifts and high intelligence the convolutions and fissures are much more developed than in the average man, and they are more developed in the latter than in apes and others of low mental capacity. There is a similar gradation among the mammals in the internal structure of the fore brain. In particular the corpus callosum, that unites the two cerebral hemispheres, is only developed in the Placentalia. Other structures—for instance, in the lateral ventricles—that seem at first to be peculiar to man, are also found in the higher apes, and these alone. It was long thought that man had certain distinctive organs in his cerebrum which were not found in any other animal. But careful examina-

tions have shown that this is not the case, but that the characteristic features of the human brain are found in a rudimentary form in the lower apes, and are more or less fully developed in the higher apes. Huxley has convincingly shown, in his *Man's Place in Nature* (1863), that the difference in the formation of the brain within the ape-group constitutes a deeper gulf between the lower and higher apes than between the higher apes and man.

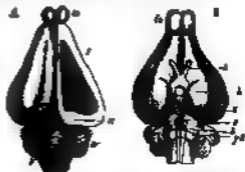


FIG. 262.—Brain of the rabbit. A, from the lateral; B, from the frontal view. (From a drawing of the brain of a rabbit, showing the cerebrum, cerebellum, and brainstem.)

impressions from the skin and the sense-organs to the central marrow, and of the motor nerves, which convey centrifugally the movements of the will from the central marrow to the muscles. All these

peripheral nerves grow out of the medullary tube (Fig. 171), and are, like it, products of the skin-sense layer.

The complete agreement in the structure and development of the psychic organs which we find between man and the highest mammals, and which can only be explained by their common origin, is of profound importance in the scientific psychology. This is only seen in its full light when we compare these morphological facts with the corresponding physiological phenomena, and remember that every psychic action requires the complete and normal condition of the correlative brain structure for its full and normal exercise. The very complex molecular movements inside the neural cells, which we describe comprehensively as "the life of the soul," can, no more exist in the vertebrate, and (therefore) in man, without their organs than the circulation

without the heart and blood. And as the cerebral marrow develops in man from the same medullary tube as that of the other vertebrates, and as man shares the characteristic structure of his cerebrum (the organ of thought) with the antelope and ape, his psychic life also must have the same origin as theirs.

If we appreciate the full weight of these morphological and physiological facts, and put a proper phylogenetic interpretation on the observations of embryology, we see that the older idea of the personal immortality of the human soul is scientifically unreasonable. Death puts an end, in man as in any other vertebrate, to the physiological function of the cerebral neurones, the countless microscopic ganglionic cells, the collective activity of which is known as "the soul." I have shown this fully in the eleventh chapter of my *Study of the Unconscious*.

CHAPTER XXV.

EVOLUTION OF THE SENSE-ORGANS

THE sense-organs are indubitably among the most important and interesting parts of the human body; they are the organs by means of which we obtain our knowledge of objects in the surrounding world. *Nihil est in intellectu quod non prius fuerit in sensu*. They are the first windows of the life of the soul. There is no other part of the body in which we discover such elaborate anatomical structures, co-operating with a definite purpose; and there is no other organ in which the wonderful and purposive structure seems so clearly to compel us to admit a Creator and a preconceived plan. Hence we find special efforts made by dualists to draw our attention here to the "wisdom of the Creator" and the design visible in his works. As a matter of fact, you will discover, on mature reflection, that on this theory the Creator is at bottom only playing the part of a clever mechanic or watch-maker; all these beautiful teleological ideas of Creator and creation are

based, in the long run, on a similar childish anthropomorphism.

However, we must grant that at the first glance the teleological theory seems to give the simplest and most satisfactory explanation of these purposive structures. If we merely examine the structure and functions of the most advanced sense-organs, it seems impossible to explain them without postulating a creative act. Yet evolution shows us quite clearly that this popular idea is totally wrong. With its assistance we discover that the purposive and remarkable sense-organs were developed, like all other organs, without any preconceived design—developed by the same mechanical process of natural selection, the same constant correlation of adaptation and heredity, by which the other purposive structures in the animal frame were slowly and gradually brought forth in the struggle for life.

Like most other Vertebrates, man has six sensory organs, which serve for eight

different kinds of sensations. The skin serves for sensations of pressure and temperature. This is the oldest, lowest, and vaguest of the sense-organs; it is distributed over the surface of the body. The other sensory activities are localized. The nasal nerve is bound up with the skin of the external nasal organs, the sense of taste with the mucous lining of the mouth (tongue and palate), and the sense of smell with the mucous lining of the nasal cavity. For the two most advanced and most highly differentiated sensory functions there are special and very elaborate mechanical structures—the eye for the sense of sight, and the ear for the sense of hearing and sense of equilibrium.

Comparative anatomy and physiology teach us that there are no differentiated sense-organs in the lower animals; all their sensations are received by the surface of the skin. The undifferentiated skin-layer or ectoderm of the Gastraea is the simple stratum of cells from which the differentiated sense-organs of all the Metazoa (including the Vertebrates) have been evolved. Starting from the assumption that necessarily only the superficial parts of the body, which are in direct touch with the outer world, could be concerned in the origin of sensation, we can see at once that the sense-organs also must have arisen there. This is really the case. The chief part of all the sense-organs originates from the skin-sensory layer, partly directly from the body plate, partly from the brain, the foremost part of the medullary tube, what is here separated from the body plate. If we compare the embryonic development of the various sense-organs, we see that they all make their appearance in the simplest conceivable form: the wonderful contrivances that make the higher sense-organs among the most remarkable and elaborate structures in the body develop only gradually. In the phylogenetic explanation of these comparative anatomy and ontogeny achieve their greatest triumphs. But at first all the sense-organs are merely parts of the skin in which sensory nerves spread. These nerves themselves were originally of a homogeneous character. The different functions or specific energies of the differentiated sense-nerves were only gradually developed by division of labour. At the same time, their simple terminal expansions in the skin were converted

The great shortcomings of these historical facts in comparison with the life of the soul is not difficult to see. The whole philosophy of the future will be transformed as soon as psychology takes cognizance of these genetic phenomena and makes them the basis of its speculations. When we examine impartially the mistakes of psychology that have been published by the most distinguished empirical philosophers and are still widely distributed, we are astonished at the method with which the authors raise their airy metaphysical speculations, repudiations of the momentous embryological facts that completely refute them. Yet the science of evolution, in conjunction with the great advance of the comparative anatomy and physiology of the vertebrates, provides the not sound empirical basis of a second structure.



Do you—Head of a church? System A from the outside may be wrong, but it's usually your people growing a weed that is taking up more of your field money up. (The dew are symptoms of the disease itself.) (W. H. Auden)

In respect of the terminal endoneurons of the sensory nerves, we can distinguish the nervous sense-organs in three groups, which correspond to three stages of development. The first group comprises those organs the nerves of which spread out quite deeply in the free surface of the skin (olfactory organs of the snout of prawns, warble, and sea). In the second group the nerves spread out in the mucous coat of cavities which are at first depressions in or invaginations of the skin (organs of the sense of smell and taste). The third group is formed of the very delicate organs, the nerves of which spread out in an internal vesicle, separated from the skin (organs of the sense of static pressure, and touch).

There is little to be said of the development of the lower vertebrates. The

other Gnathostomes, of two completely separated halves, the right and left cavities. They are divided by a vertical partition, so that the right nostril leads into the right cavity alone and the left nostril into the left cavity. They open internally (and separately) by the posterior nasal apertures into the pharynx, so that we can get direct into the gullet through the nasal passages without touching the mouth. This is the way the air usually passes in respiration; the rostrum being closed, it goes through the nose into the gullet, and through the larynx and bronchial tubes into the lungs. The nasal cavities are separated from the mouth by the horizontal bony palate, to which is attached behind (as a dependent process) the soft palate with the uvula. In the upper and broader parts of the nasal cavities the olfactory nerves, the first pair of cerebral nerves, expand in the mucosa and which cluster them. The terminal branches of it spread partly over the septum (partition), partly on the side walls of the internal cavity, to which are attached the turbinate bones. These bones are much more developed in many of the higher mammals than in man, but there are three of them in all mammals. The sensation of smell arises by the passage of a current of air containing odorous matter over the mucosa lining of the cavities, and stimulating the olfactory cells of the nerve-endings.

Man has all the features which distinguish the olfactory organ of the mammals from that of the lower Vertebrates. In all essential points the human nose entirely resembles that of the *Catarrhine apes*, some of which have quite a few more external nores (compare the face of the long-nosed apes). However, the first structure of the olfactory organ in the human embryo gives an indication of the future simple proportions of our *Catarrhine* nose. It has the form in which we find it permanently in the fisher—a couple of simple depressions in the skin at the outer surface of the head. We find three blind olfactory pits in all the fishes; sometimes they lie near the eyes, sometimes more forward at the point of the snout, sometimes lower down, near the mouth (Fig. 299).

This first rudimentary structure of the double nose is the same in all the *Gnathostomes*; it has no connection with the primitive mouth. But even in a section

begins to make its appearance, a furrow in the surface of the skin running from each side of the nasal pit to the nearest corner of the mouth. This furrow, the nasal groove or furrow (Fig. 305 *r*), is very important. In many of the sharks, such as the *Sphyrna*, a special process of the frontal skin, the nasal fold or internal nasal process, is formed internally over the groove (*n*, *n'*). In contrast to this the outer edge of the furrow rises in an "external nasal process." As the two processes meet and coalesce over the

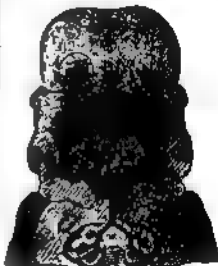


FIG. 305.—Frontal section of the mouth and nasal cavity of a human embryo, back and forth long. (Issued by H. Meyer, 1897.) The vertical section (b) shows the nasal pit (n) and the nasal fold (n') in the upper part of the figure and the nasal pit (n) in the lower part. The nasal pit (n) is the point of the snout, and the nasal fold (n') is the point of the snout. The nasal pit (n) is the point of the snout, and the nasal fold (n') is the point of the snout.

nasal groove in the *Dipnoans* and *Amphibia*, it is converted into a canal, the nasal canal. Henceforth we can penetrate from the external pit through the nasal canal direct into the mouth, which has been formed quite independently. In the *Dipnoans* and the lower *Amphibia* the internal aperture of the nasal canal lies in front (behind the eye); in the higher *Amphibia* it is right behind. Finally, in the three higher classes of Vertebrates the primary mouth-cavity is

grows out into two distinct cavities—the upper (secondary) nasal cavity and the lower (secondary) mouth-cavity. The nasal cavity is then divided by the construction of the vertical septum into two halves—right and left.

Comparative anatomy shows us to-day, in the series of the double-nasal Vertebrates, from the fish up to man, all the different stages in the development of the nose, which the advanced olfactory organ of the higher mammal has passed through at various periods in the course of its phylogeny. It first appears in the embryo of man, and the higher Vertebrates, in which the double fish-like persists throughout life. At an early stage, before there is any trace of the characteristic human face, a pair of small pits are formed in the head over the original mouth-cavity; these were first discovered by Huxley, and rightly called the "olfactory pit" (Figs. 300 a, 301 a).



FIG. 300.—Embryonic stage of the mouth-cavity. (a) The olfactory pits (b) divide the original mouth-cavity into the lower secondary mouth (c) and the upper nasal cavity. The latter is then divided by the vertical septum (d) into two halves (e, f). (From Degener's.)

These primitive nasal pits are quite separate from the rudimentary mouth, which also originates as a pit-like depression in the skin, in front of the blast pore and of the gut. Both the pair of nasal pits and the single mouth-pit (Fig. 300 a) are stuffed with the horny plate. The original separation of the former from the latter is, however, presently abolished, a process forming above the mouth-pit—the "frontal process" (Fig. 301 a). Its outer edge rises to the right and left in the shape of two lateral processes; these are the inner nasal processes or folds (a). Opposite to these a parallel ridge is formed on either side between the eye and the nasal pit; these are the outer nasal processes (ab). Thus between the inner and outer nasal processes a groove-like depression is formed on either side, which leads from the mouth

pit towards the mouth-pit (a). This groove is, as the reader will guess, the same as the furrow or groove that we have already seen in the shark (Fig. 302 a). As the parallel ridges of the inner and outer nasal processes bend towards each other and join above the nasal groove, this is converted into a tube, the primitive nasal canal. Hence the nose of man and all the other Amniotes consists at this embryonic stage of a couple of narrow tubes, the nasal canals, which lead from the outer surface of the forehead to the rudimentary mouth. This transitional condition resembles that in which we find the nose permanently in the Dipnoans and Amplexoids.

A cone-shaped structure, which grows from below towards the lower ends of the two nasal processes and joins with them, plays no important part in the construction of the open nasal groove into the closed canal. This is the upper-jaw process (Figs. 301-310 of Bloor) the mouth-pit on the gill-arches, which are surrounded by the gill-lobes. The first of these gill-arches, and the most important for our purpose, which it may call the maxillary jaw-arch, forms the skeleton of the jaw. Above it on the head a small process grows out of the first gill-arch, this is the upper-jaw process. The first gill-arch itself develops a cartilage at one of its inner ends, the "Meckel cartilage" (named after its discoverer), on the outer surface of which the lower jaw is formed (Figs. 301-310 b). The upper-jaw process forms the chief part of the skeleton of that jaw, the premaxilla, and the premaxillary bone. On its outer side is afterwards formed the upper-jaw bone, in the maxillary series, while the middle part of the skeleton of the upper jaw, the intermaxillary, develops from the foremost part of the frontal process.

The two upper-jaw processes are of great importance in the further development of the face. From them is formed, growing into the primitive mouth-cavity, the important horizontal partition (the palate) that divides the former into two distinct cavities. The upper cavity, into which the nasal canals open, now develops into the nasal cavity, the air-passages and the organ of smell. The lower cavity forms the permanent secondary mouth (Fig. 312 a), the food-passages and the organ of taste. Both the upper and lower cavities open laterally into the gullet (pharynx). The lower

palate that separates them is formed by the joining of two lateral halves, the horizontal plates of the two upper-jaw processes, or the palato-plates (*p*). When these do not, sometimes, completely join in the middle, a longitudinal cleft remains, through which we can penetrate from the mouth straight into the nasal cavity. This is the malformation known as "wolf's throat." "Harelip" is the lesser form of the same defect. At the same time as the horizontal partition of the hard palate a vertical partition is formed by which the single nasal cavity is divided into two nostrils—a right and left half (Fig. 312 *m, n*).

skull, growing forwards from behind. The characteristic human nose is formed very late. Much stress is at times laid on this organ as an exclusive privilege of man. But there are apes that have similar noses, such as the long-nosed ape.

The evolution of the eye is not less interesting and instructive than that of the nose. Although this noblest of the sensory organs is one of the most complicated and purposeful on account of its optic perfection and remarkable structure, it nevertheless develops, without pre-conceived design, from a simple process of the outer germinal layer. The fully-formed human eye is a round capsule, the



FIG. 312



FIG. 314

FIGS. 312 AND 314.—Upper end of the body of a human embryo, one-fourth of an inch long of the eighth week, Fig. 312 from the left, Fig. 314 from the front. The organs of the nose and the upper lip have two nostrils and originally separate halves can be clearly seen. Nose and upper lip overlarge in proportion to the rest of the face, and especially to the lower lip. (From Haeckel.)

The double nose has now acquired the characteristic form that man shares with the other mammals. Its further development is easy to follow; it consists of the formation of the inner and outer processes of the walls of the two cavities. The external nose is not formed until long after all these essential parts of the internal organ of smell. The first traces of it in the human embryo are found about the middle of the second month (Figs. 313-316). As can be seen in any human embryo during the first month, there is at first no trace of the external nose. It only develops afterwards from the foremost nasal part of the primitive

eye-ball (Fig. 317). This lies in the body cavity of the skull, surrounded by protective fat and motor branches. The greater part of it is taken up with a watery fluid, transparent gelatinous substance, the corpus vitreum. The crystalline lens is fitted into the anterior surface of the ball (Fig. 317 *l*). It is a lensular, bi-concave, transparent body, the most important of the refractive media in the eye. Of this group we have, besides the corpus vitreum and the lens, the watery fluid (*aqueous humor*) that is found in front of the lens (at the letter *m* in Fig. 317). These three transparent refractive media, by which the rays of light that

enter the eye are broken up and refocused, are enclosed in a solid round capsule, composed of several different coats, something like the concentric layers of an onion. The outermost and



FIG. 145.—Face of a human embryo, very early stage. (From *Development*.) Junction of the nasal process (or eye) with the upper lip (pharynx) is visible at the beginning.

thickest of these envelopes is the white sclerotic coat of the eye. It consists of tough white connective tissue. In front of the lens a circular, strongly-curved, transparent plate is fixed into the sclerotic, like the glass of a watch—the cornea (6). At its outer surface the cornea is covered with a very thin layer of the epidermis, this is known as the conjunctiva. It goes from the cornea over the inner surface of the eye-lids, the upper and lower folds which we draw over the eye in closing it. At the inner corner of the eye we have a rudimentary organ in the shape of the bulb of a third (inner) eyelid, which is greatly developed, as “nictitating (winking) membrane,” in the low vertebrates (p. 32). Underneath the upper eyelid are the lachrymal glands, the product of which, the lachrymal fluid, keeps the outer surface of the eye smooth and clear.

Immediately under the sclerotic we find a very delicate, dark-red membrane, very rich in blood-vessels—the choroid coat—and inside this the iris (7), the expansion of the optic nerve (1). The latter is the second cerebral nerve. It projects from the optic thalamus (the second cerebral

vesicle) to the eye, penetrates its outer envelope, and then spreads out like a net between the choroid and the corpus vitreum. Between the retina and the choroid there is a very delicate membrane, which is usually (but strongly) associated with the latter. This is the black pigment-membrane (8). It consists of a single stratum of graceful, hexagonal, regularly-joined cells, full of granules of black colouring matter. This pigment membrane clothes not only the inner surface of the choroid proper, but also the hind surface of its anterior muscular constriction, which grows the edge of the lens on front as a circular membrane, and arrests the rays of light at the sides. Thus is the well-known iris of the eye (6), coloured differently in different individuals (blue, grey, brown, etc.); it forms the anterior border of the choroid. The circular opening that is left in the middle is the pupil, through which the rays of light penetrate into the eye. At the point where the iris leaves the anterior border of the choroid proper the latter is very thick, and forms a delicate crown of folds (9), which surrounds the edge of the lens with about twenty large and many smaller rays (resembling *silene*).

At a very early stage a couple of pear-shaped vesicles develop from the foremost part of the first cerebral vesicle in the embryo of man and the other Vertebrates (Figs. 224, 225, 226). These growths are the primary optic vesicles. They are at first directed outward and forward, but presently grow downward, so that, after the complete separation of the first cerebral vesicle, they lie at the base of the intermediate brain. The more caudal of these pear-shaped vesicles, which soon attain a considerable size, are closely connected with the ventricle of the intermediate brain by their hollow stems. They are covered externally by the epidermis.

At the point where this vesicle into direct contact with the most curved part of the primary optic vesicle there is a thickening (1) and also a depression (2) of the horny plate (Fig. 318, 2). This pit, which we may call the lens-pit, is converted into a closed sac, the thick-



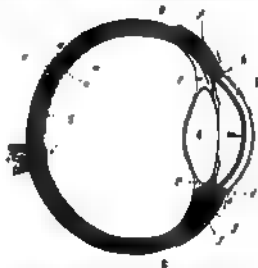
FIG. 146.—Face of a human embryo, right vesicle and (from the eye).

walled lens-veinlets (2, 3), the thick edges of the pit joining together above it. In the same way in which the endothelial tube separates from the outer germinal layer, we now see this lens-mac across itself entirely from the horny plate (A) its source of origin. The hollow of the sac is afterwards filled with the cells of the black walls, and thus we get the solid crystalline lens. This is, therefore, a purely epidermic structure. Together with the lens the small underlying piece of corneum-plate also separates from the skin.

As the lens separates from the porous vitreous and grows inward, it necessarily hollows out the contiguous primary optic vesicle (Fig. 310, 1-3). This is done in just the same way as the invagination of the blastula, which gives rise in the gastrula to the amphibole (Fig. 311 C-F). In both cases the hollowing out of the closed vesicle is on one side, goes so far that at least the inner, folded part touches the outer, not folded part, and the cavity disappears. As in the gastrula the first part is converted into the endoderm and the latter into the ectoderm, so in the invagination of the primary optic vesicle the retina (*r*) is formed from the first (inner) part, and the black pigment membrane (*a*) from the latter (outer, non-invaginated) part. The hollow then of the primary optic vesicle is converted into the optic nerve. The lens (*l*), which has so important a part in this process, but at first directly on the invaginated part, or the retina (*r*). But they soon separate, a new structure, the corpus vitreous (*g*), growing between them. While the lens is being detached and is causing the invagination of the primary optic vesicle, another invagination is taking place from below: this proceeds from the superficial part of the skin-plate layer—the corium of the head. Belling and under the lens a hat-shaped process rises from the cuticle-plate (Fig. 319 *g*), hollows out the cup-shaped optic vesicle from below, and presses between the lens (*l*) and the retina (*r*). In this way the optic vesicle acquires the form of a hood.

Finally, a complete fibrous envelope, the fibrous capsule of the eyeball, is

formed about the secondary optic vesicle and its stem (the secondary optic nerve). It migrates from the part of the head-plate which immediately encloses the eye. This fibrous envelope takes the form of a closed round vesicle, surrounding the whole of the ball and pushing between the lens and the horny plate at its outer side. The round wall of the capsule soon divides into two different membranes by surface-cleavage. The inner membrane becomes the choroid or vascular coat, and in front the ciliary mass and iris. The outer membrane is

[illegible]

converted into the white protective or sclerotic coat—in fact, the transparent cornea. The eye is now formed in all its essential parts. The further development—the complicated differentiation and composition of the various parts—is a matter of detail.

The chief point in this remarkable evolution of the eye is the circumstance that the optic nerve, the retina, and the pigment membrane originate really from a part of the brain—an outgrowth of the intermediate brain—while the lens, the chief refraction body, develops from the outer skin. From the skin—the horny

plate—also arises the delicate conjunctiva, which afterwards covers the outer surface of the eyeball. The lachrymal glands are ramified growths from the conjunctiva (Fig. 28b). All these important parts of



FIG. 28. — Eye of the shark embryo as represented by three stages (1, 2, 3). 1. From an embryo 1 mm. long. 2. From an embryo 2 mm. long. 3. From an embryo 3 mm. long. 1. The eye is a simple spot. 2. The eye is a simple spot with a lens. 3. The eye is a simple spot with a lens and iris. 1. The eye is a simple spot. 2. The eye is a simple spot with a lens. 3. The eye is a simple spot with a lens and iris.

the eye are products of the outer germinal layer. The remaining parts—the corpus vitreum (with the vascular capsule of the lens), the choroid (with the iris), and the sclerotic (with the cornea)—are formed from the middle germinal layer.

The outer projection of the eye, the eyelids, are merely folds of the skin, which are formed in the third month of human embryonic life. In the fourth month the upper eyelid reaches the brow, and the eye remains covered with them until birth. As a rule, they open wide shortly before birth (sometimes only after birth). Our craniate ancestors had a third eyelid, the nictitating membrane, which was drawn over the eye from its inner angle. It is still found in many of the Selachii and Amniota. In the ape and man it has degenerated, and there is now only a small relic of it as the inner corner of the eye, the caruncular fold, a useless rudimentary organ (cf. p. 32). The ape and man have also lost the Harderian gland that opened under the nictitating membrane; we find this in the rest of the mammals, and the birds, reptiles, and amphibians.

The peculiar embryonic development of the vertebrate eye does not enable us to draw any definite conclusions as to its obscure phylogeny; it is clearly convergent to a great extent, or obscured by the reduction and curtailment of its original features. It is probable that many of the earlier stages of its phylogeny have disappeared without leaving a trace,

It can only be said positively that the peculiar ontogeny of the complicated optic apparatus in man follows just the same laws as in all the other Vertebrates. Their eye is a part of the fore brain, which has grown forward towards the skin, not an original cutaneous sense-organ, as in the Invertebrates.

The vertebrate ear resembles the eye and nose in many important respects, but is different in others, in its development. The accessory organ in the fully developed man is like that of the other mammals, and especially the ape, in the main features. As in them, it consists of two chief parts—an apparatus for conducting sound (external and middle ear) and an apparatus for the sensation of sound (internal ear). The external ear opens in the skull at the side of the head (Fig. 32a). From this point the external passage (b), about an inch in length, leads into the head. The inner end of it is closed by the tympanum, a vertical, but not quite upright, thin membrane of an oval shape (c). This tympanum separates the external passage from the tympanic cavity (d). This is a small cavity filled with air, in the temporal bone; it is connected with the mouth by a special tube.

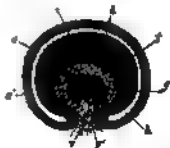


FIG. 32. — Horizontal transverse section of the ear of a human embryo, four weeks old (magnified one hundred times). (From Kükenthal.) 1. The external passage (b) is as thick as the diameter of the central artery; it is a vascular body (consisting of a piece of the dorsal aorta) which is pushed behind the lens (c). 2. The tympanum (c) is a vascular body (consisting of a piece of the dorsal aorta) which is pushed behind the lens (c). 3. The tympanic cavity (d) is a small cavity filled with air, in the temporal bone; it is connected with the mouth by a special tube.

This tube is rather longer, but much narrower, than the outer passage, leads inward obliquely from the anterior wall of the tympanic cavity, and opens in the throat below, behind the nasal

opening. It is called the Eustachian tube (e); it serves to equalize the pressure of the air within the tympanic cavity and the outer atmosphere that enters by the external meatus. Note

[illegible]

the Eustachian tube and the tympanic cavity are lined with a thin mucous coat, which is a direct continuation of the mucous lining of the throat. Inside the tympanic cavity there are three small bones which are known from their shape as the hammer, anvil, and stirrup (Fig. 300, f, g, h). The hammer (f) is the outermost, next to the tympanum. The anvil (g) lies between the other two, above and inside the hammer. The stirrup (h) lies inside the anvil, and touches with its base the outer wall of the internal ear, or muscular vesicle. All these parts of the apparatus are movable and belong to the apparatus for conducting sound. Their chief task is to convey the waves of sound through the thick wall of the head to the inner-lying muscular vesicle. They are not found at all in the fishes. In those the waves of sound are conveyed directly by the wall of the head to the muscular vesicle.

The Internal Accounting for the transaction

of sound, which renders the waves of sound from the conducting apparatus, consists in man and all other mammals of a closed sacculatory vesicle filled with fluid and an auditory nerve, the mode of which expand over the wall of this vesicle. The vibrations of the sound-waves are conveyed by these media to the nerve-fibrils. In the labyrinthine water that fills the sacculatory vesicle there are small sinuses at the points of entry of the acoustic nerve, which are composed of groups of microscopic calcareous crystals (otoliths). The sacculatory organ of most of the invertebrates has substantially the same composition. It usually consists of a closed vesicle, filled with fluid, and containing cilia, with the acoustic nerve expanding on its wall. But, while the auditory vesicle is usually of a simple round or oval shape in the invertebrates, it has in the Vertebrates a special and curious structure, the labyrinth. This (the sacculatory) labyrinth is enclosed in a bony capsule of the same shape, the osseous labyrinth (Fig. 321), and this lies in the middle of the porous bone of the skull. The labyrinth is divided into two vesicles in all the Gnathostomes. The larger one is called the utricle, and has three arched appendages, called the "semi-circular canals" (c, d, e). The smaller vesicle is called the saccule, and is connected with a peculiar appendage, with (in man and the higher mammals) a spiral form something like a snail's shell, and therefore called the cochlea (in coil, *q*). On the thin wall of this delicate labyrinth the acoustic nerve, which comes from the after-brain, spreads out in most elaborate fashion. It divides



Figs. 30-31.—The long tubercles of the brownish leaf beetle, *Meloidae*, & cochineal, *Coccinellidae*, of the same genus, & other small, oval tubercles, of various genera, of the same family.

The first structure of this highly elaborate organ is very simple in the embryo of man and all the other Crustacea. It is a

pit-like depression in the skin. At the back part of the head at both sides, near the after brain, a small thickening of the horny plate is formed at the upper end of the second gill-cleft (Fig. 320 A & B). This sinks into a sort of pit, and moves from the epidermis, just as the lens of the eye does. In this way is formed at each side, directly under the horny plate of the back part of the head, a small vesicle filled with fluid, the primitive sensory vesicle, or the primary labyrinth. As it separates from its source, the horny plate, and presses forwards and backwards into the skull, it changes from round to pear-shaped (Figs. 322 B & C, 323 d). The outer part of it is lengthened into a thin stem, which at first still grows outwardly by a secondary canal. This is the labyrinthine appendage (Fig. 323 A). In the lower Vertebrates it develops into a special cavity filled with

fluid in the shape of simple pouch-like invaginations of the utricle (*ear and eye*). The edges join together in the middle part of each fold, and separate from the utricle, the two ends remaining in open connection with its cavity. All the Gnathostomes have these three canal-like sacs, whereas among the Cyclostomes the lampreys have only two and the hag-fishes only one. The very simplest structure of the cochlea, one of the most elaborate and wonderful outcomes of adaptation in the mammalian body, develops originally in very simple fashion as a flask-like projection from the sacculus. As Hesse and Reissner have pointed out, we find the same ontogenetic stages of its growth represented permanently in the organs of the higher Vertebrates. The cochlea is wanting even in the *Monoecraea*, and is restricted to the rest of the mammals and man.



FIG. 322.—Development of the auditory apparatus of *Amphioxus*. A, B, C, D, various successive stages of the development of the auditory apparatus. A, B, C, D, various successive stages of the development of the auditory apparatus. A, B, C, D, various successive stages of the development of the auditory apparatus.

calciferous crystals which remains open permanently in some of the primitive fishes, and opens outwards in the upper part of the skull. But in the mammals the labyrinthine appendage degenerates. In them it has only a phylogenetic interest as a rudimentary organ, with no actual physiological significance. The median role of it passes through the wall of the periotic bone in the shape of a narrow canal, and included the vestibular appendage.

It is only the inner and lower bulbous part of the separated auditory vesicle that develops into the highly complex and differentiated structure that is afterwards known as the secondary labyrinth. This vesicle divides at an early stage into an upper and larger and a lower and smaller section. From the one we get the *utricle* with the semi-circular canals; from the other the *sacculus* and the *codium*. (Fig. 320 C). The canals are

derived phylogenetically from an ordinary contractile nerve, and is of quite different origin from the optic and olfactory nerves, which both represent direct outgrowths of the brain. In this respect the auditory organ is essentially different from the organs of sight and smell. The acoustic nerve is formed from ectodermic cells of the hind brain, and develops from the nervous structure that appears at its dorsal limit. On the other hand, all the membranous, cartilaginous, and osseous coverings of the labyrinth are formed from the mesodermic blastopore.

The apparatus for conducting sound which we find in the external and middle ear of vertebrates develops quite separately from the apparatus for the sensation of sound. It is both phylogenetically and ontogenetically an independent secondary formation, a later accession to

the primary internal ear. Nevertheless, its development is not less interesting, and is explained with the same ease by comparative anatomy. In all the fishes and in the lowest Vertebrates there is no



FIG. 34. Primitive skull of the lampbrush fish, four months old, external surface, left half with air cavity, as in a. b is the first part of the external meatus, in which the first vascular vessels (a. blood, internal carotid, sublingual, and other bloods), a pair-shaped primary auditory vesicle (secondary hemispheres), a b, secondary auditory vesicle (a. b), a part of the hypophysis, c central process of the skull. (From Huxley.)

special apparatus for conducting sound. In external or middle ear, they have only a labyrinth, an internal ear, which lies within the skull. They are without the tympanum and tympanic cavity, and all its appendages. From some observations made in the last few decades it seems that many of the fishes (of course cannot distinguish tones, their labyrinth seems to be usually (if not exclusively) an organ for the sense of space (or equilibrium), if it is destroyed, the fishes lose their balance and fall. In the opinion of most physiologists this applies also to many of the Invertebrates (including the water snails of the Vertebrates). The round vesicles which are considered to be their auditory vesicles, and which contain no otolith, are supposed to be merely organs of the sense of space ("static vesicles or statocysts").

The middle ear makes its first appearance in the amphibia class, where we find a tympanum, tympanic cavity, and Eustachian tube; these animals, and all terrestrial Vertebrates, certainly have the faculty of hearing. All these essential parts of the middle ear originate from the first gill-cleft and its surrounding part; in the Selachii this remains throughout life an open squaring-hole, and first between the first and second gill-arch. In the embryo of the higher Vertebrates it closes up in the center, and thus forms

the tympanic membrane. The outlying extremity of the first gill-cleft is the rudiment of the external meatus. From its inner part we get the tympanic cavity, and, further inward still, the Eustachian tube. Connected with this is the development of the three bones of the mammal ear from the first two gill-arches; the hammer and anvil are formed from the first, the stirrup from the upper part of the second, gill-arch.

Finally, the shell (pinna or concha) and external meatus (passage to the tympanum) of the outer ear are developed in a very simple fashion from the skin that borders the external aperture of the first gill-cleft. The shell rises in the shape of a circular fold of the skin, in which cartilage and muscles are afterwards formed (Figs. 373 and 375). This organ is only found in the Mammalian class. It is very rudimentary in the lowest mammal, the Marsupial. In the others it is found at very different stages of development, and sometimes of degeneration. It is degenerate in most of the aquatic mammals. The majority of them have lost it altogether—for instance, the walrus and whales and most of the seals. On the other hand, the pinna is



FIG. 35. The rudimentary structure of the ear in the lampbrush fish. a hearing muscle (a. auditory), b hearing vesicle (b. auditory), c auditory vesicle (c. auditory), d large muscle of the jaw (d. auditory), e small muscle of the jaw (e. auditory), f muscle of the jaw of the ear (f. auditory), g auditory vesicle (g. auditory), h auditory. (From H. Huxley.)

well developed in the great majority of the Mammals and Pinnipeds; it catches and collects the waves of sound, and is equipped with a very elaborate muscular apparatus, by means of which the pinna

can be turned freely in any direction and its shape be altered. It is well known how readily domestic animals—horses, cows, dogs, hares, etc.—pivot their ears and move them in different directions. Most of the apes do the same, and our earlier ape ancestors were also able to do it. But our later simian ancestors, which we have in common with the anthropoid apes, abandoned the use of these muscles, and they gradually became rudimentary and useless. However, we possess them still (Fig. 323). In fact, some men can still move their ears a little backward and forward by means of the drawing and withdrawing muscles (*b* and *c*); with practice this faculty can be much improved. But no man can now lift up his ears by the raising muscle (*a*), or change the shape of them by the small inner muscles (*d*, *e*, *f*, *g*). These muscles were very useful to our ancestors, but are of no consequence to us. This applies to most of the anthropoid apes as well.

We also share with the higher anthropoid apes (gorilla, chimpanzee, and orang) the characteristic form of the human outer ear, especially the folded border, the helix and the lobe. The lower apes have pointed ears, without folded border or lobe, like the other mammals. But Darwin has shown that at the upper

part of the folded border there is in many men a small pointed process, which most of us do not possess. In some individuals this process is well developed. It can only be explained as the relic of the original point of the ear, which has been turned sideways in consequence of the curving of the edge. If we compare the pinna of man and the various apes in this respect, we find that they present a connected series of degenerate structures. In the common catarrhine ancestors of the anthropoids and man the degeneration set in with the folding together of the pinna. This brought about the helix in the ear, in which we find the significant angle which represents the relic of the original point of the ear in our earliest simian ancestors. Here again, therefore comparative anatomy enables us to trace with certainty the human ear to the smaller, but more developed, organ of the lower mammals. At the same time, comparative physiology shows that it was a more or less useful implement in the latter, but it is quite useless in the anthropoids and man. The conducting of the sound has scarcely been affected by the loss of the pinna. We have also in this the explanation of the extraordinary variety in the shape and size of the shell of the ear in different men; in this it resembles other rudimentary organs.

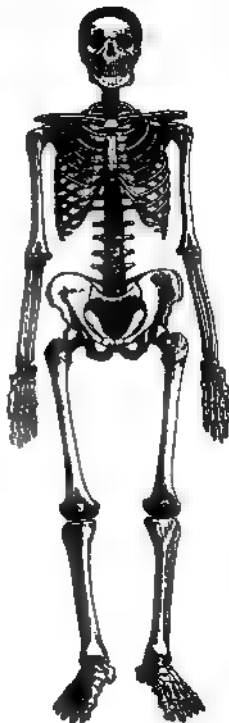
CHAPTER XXVI.

EVOLUTION OF THE ORGANS OF MOVEMENT

THE peculiar structure of the locomotive apparatus is one of the features that are most distinctive of the vertebrate class. The chief part of this apparatus is formed, as in all the higher animals, by the active organs of movement, the muscles; in consequence of their contractility they have the power to draw up and shorten themselves. This affects the movement of the various parts of the body, and thus the whole body is conveyed from place to place. But the

arrangement of these muscles and their relation to the solid skeleton are different in the Vertebrates from the Invertebrates.

In most of the lower animals, especially the Platyodes and Vermalis, we find that the muscles form a simple, thin layer of flesh immediately underneath the skin. This muscular layer is very closely connected with the skin itself; it is the same in the Mollusc stem. Even in the large division of the Articulata, the class of crabs, spiders, myriapods, and



insects, we find a similar feature, with the difference that in this case the skin forms a solid armour—a rigid cutaneous skeleton made of chitine (and often also of carbonates of lime).

This external chitineous coat undergoes a very elaborate articulation both on the trunk and the limbs of the Arthropoda, and in consequence the muscular system also, the contractile fibres of which are attached inside the chitineous tubes, is highly articulated. The Vertebrates form a direct contrast to this. In them alone a well-developed, or cartilaginous, or bony, internal skeleton is developed, in which the muscles are attached. This bony skeleton is a complex bony apparatus, or framework of substance in rigid parts, the axis of the limbs, or the haem, are brought together by the activity of the muscles, as if by chain supports. This admirable mechanism, especially its independence in the vertebral column, is a special feature of the Vertebrates, and has given the name to the group.

FIG. 37.—The human vertebral column (standing upright) from the right side (from H. Moore).

In order to get a clear idea of the development of the skeleton of the human skeleton, we must first examine its composition in the adult form (Fig. 37, the human skeleton seen from the right, Fig. 38, front view of the whole skeleton). As in other mammals, we distinguish first between the axial or dorsal skeleton and the skeleton of the limbs. The axial skeleton consists of the vertebral column (the skeleton of the trunk) and the skull (skeleton of the head); the latter is a particularly modified part of the former. An appendage of the vertebral column we have

the ribs, and of the skull we have the brain case, the lower jaw, and the other products of the gill-arches.

The skeleton of the limbs or extremities is composed of two groups of parts—the skeleton of the extremities proper and the auto-skeleton, which connects these with the vertebral column. The auto-skeleton of the arms (or fore legs) is the shoulder-girdle; the auto-skeleton of the legs (or hind legs) is the pelvic girdle.

The vertebral column (Fig. 37) in man is composed of thirty-three to thirty-five ring-shaped bones in a continuous series (about each other, in man's upright position). These vertebrae are separated from each other by elastic ligaments, and at the same time connected by joints, so that the whole column forms a firm and solid, but flexible and elastic, axial skeleton, moving freely in all directions. The vertebrae differ in shape and construction at the various parts of the trunk, and we distinguish the following groups in the series, beginning at the top: seven cervical vertebrae, twelve dorsal vertebrae, five lumbar vertebrae, five sacral vertebrae, and four to six caudal vertebrae. The uppermost, or those next to the skull, are the cervical vertebrae (Fig. 39); they have a hole in each of the lateral processes. There are seven of these vertebrae

in man and almost all the other mammals, even the whale is as long as that of the camel or giraffe, or as short as that of the mole or hedgehog. The constant number, which has been explained (due to adaptation), is a strong proof of the common descent of the mammals; it is easily explained by faithful heredity from a common ancestor, a proto-mammal constructed with seven cervical vertebrae. If each species had been created separately, it would have been better to have given the long-necked mammals more, and the short-necked mammals less, cervical vertebrae. Next to them come the dorsal (or posterior)



FIG. 39.—A view of the cervical vertebrae (neck vertebrae) from a single vertebra, showing the hole in the lateral process (from H. Moore).

Next to them come the dorsal (or posterior)

vertebrae, which number twelve to thirteen (usually twelve) in man, and most of the other mammals. Each dorsal vertebra (Fig. 165) has at the side, connected by joints, a couple of ribs, long bony arches that lie in and protect the chest.

The twelve pairs of ribs, together with the connecting intercostal muscles and the sternum, which joins the ends of the right and left ribs in front, form the chest (thorax). In this strong and elastic frame are the lungs, and between them the heart. Next to the dorsal vertebra comes a short but stronger section of the column, formed of five large vertebrae. These are the lumbar vertebrae (Fig. 166); they have no ribs and so take in the transverse process. To

FIG. 165.—Three dorsal vertebrae from a human embryo. Each vertebra has a central body, a neural arch, a neural process, a pedicle, a transverse process, a costal process, a spinous process, and a body. (From Kolliker.)

succeeds the sacral base, which is between the two halves of the pelvic girdle. The sternum is formed of five separate, but plainly blended together. Finally, we have at the end of the column a small rudimentary caudal column, the *os coccygis*. This consists of a varying number (usually four, more rarely three, or five or six) of small rudimentary vertebrae, and in a system rudimentary organs with no actual physiological significance. Morphologically, however, it is of great interest as an irrefragable proof of the descent of man and the anthropoids from long-tailed apes. On no other theory can we explain the existence of this rudimentary tail. In the earlier stages of development the tail of the human embryo protrudes considerably. It afterwards atrophies; but the ribs of the atrophied caudal vertebrae and of the rudimentary muscles that accompanied it remain permanently. Sometimes, in fact, the external tail is preserved. The older anatomists say that the tail is usually one vertebra longer in the human female than in the male (or four against five). Strehlitz says it is the reverse.

In the human vertebral column there are usually thirty-three vertebrae. It is interesting to find, however, that the

number often changes, one or two vertebrae dropping out or an additional one appearing. Often, also, a mobile rib is inserted at the last cervical or the first lumbar vertebra, so that there are then thirteen dorsal vertebrae, besides six cervical and four lumbar. In this way the configurations of the various sections of the column may take each other's place.

In order to understand the embryology of the human vertebral column we must first carefully consider the shape and construction of the vertebrae. Each vertebra has, in general, the shape of a wheel-ring (Figs. 164-166). The thicker portion, which is turned towards the ventral side, is called the body of the vertebra, and forms a short osseous disk; the thinner part forms a semi-circular arch, the *neural arch*, and is turned towards the back. The arches of the successive vertebrae are connected by thin intervertebral ligaments in such a way that the cavity they collectively enclose represents a long canal. In this vertebral canal we find the trunk part of the central nervous system, the spinal cord. Its head part, the brain, is enclosed by the skull, and the skull itself is merely the uppermost part of the vertebral column, discontinuously continued. The inner or ventral side of the vascular cranial capsule corresponds originally to a number of developed vertebral bodies; its ventral or dorsal side to these combined upper vertebral arches.

While the solid, osseous bodies of the vertebrae represent the real central axis of



FIG. 166.—A dorsal vertebra of the human embryo. a, neural body; b, neural arch; c, neural process; d, costal process; e, spinous process; f, body. (From Kolliker.)

the skeleton, the dorsal arches serve to protect the central marrow they enclose. But smaller arches develop on the ventral side for the protection of the viscera in the breast and belly. These lower or

ventral vertebral arches, proceeding from the ventral side of the vertebral bodies, form, in many of the lower Vertebrates, a canal in which the large blood-vessels are enclosed on the lower surface of the



FIG. 21.—Intervertebral disk of a sea-hare (*Lepidochelys*), ventral view of the disk. (From Aulic.)

vertebral column (aorta and caudal vein). In the higher Vertebrates the majority of these vertebral arches are lost or become rudimentary. But at the thoracic section of the column they develop into independent strong outworn arches, the ribs (*costae*). In reality the ribs are merely large and independent lower vertebral arches, which have lost their original connection with the vertebral bodies.

If we turn from this anatomical view; of the composition of the column to the question of its development, I may refer the reader to earlier pages with regard to the first and most important point (pp. 145-148). It will be remembered that in the human embryo and that of the other vertebrates we find at first, instead of the segmented column, only a simple unarticulated cartilaginous rod. This solid but flexible and elastic rod is the axial rod (or the *chorda dorsalis*). In the lowest Vertebrates, the Amphioxus, it retains this simple form throughout life, and permanently represents the whole internal skeleton (Fig. 310 *f*). In the Tunicates, also, the nearest invertebrate relatives of the Vertebrates, we meet the same chorda—transiently in the swimming larva tail of the Ascidia, permanently in the Copepoda (Fig. 225 *c*). Undoubtedly both the Tunicates and Ascidians have inherited the chorda from a common unsegmented stem-form; and these ancient, long-extinct ancestors of all the

chordates are our hypothetical Prochordata.

Long before there is any trace of the skull, blasta, etc., in the embryo of man or any of the higher Vertebrates—at the early stage in which the whole body is merely a tadpole-shaped embryonic shield—there appears in the middle line of the shield, directly under the medullary furrow, the simple chorda. (Cf. Figs. 231-235 *ch*). It follows the long axis of the body in the shape of a cylindrical axial rod of elastic but firm composition, equally pointed at both ends. In every case the chorda originates from the dorsal wall of the primitive gut; the cells that compose it (Fig. 328 *f*) belong to the endoderm (Figs. 256-261). At an early stage the chorda develops a transparent structureless sheath, which is secreted from its cells (Fig. 328 *g*). This chordal sheath is often called the "inner chorda-sheath," and must not be confused with the real external sheath, the mesodermal pro-chorda.

But this unsegmented primary axial skeleton is soon replaced by the segmented secondary axial skeleton, which we know as the vertebral column. The intervertebral plates (Fig. 124 *e*) differentiate from the enormous median part of the visceral layer of the ectoderm-muscle at each side of the chorda. As they grow round the chorda and ensheath it they form the skeleton plate or heterodermis layer—that is to say, the skeleton-forming stratum of cells, which provides the mobile foundation of the permanent vertebral column and skull (cranium). In the head-half of the embryo (the



FIG. 22.—Tunicate larva.

skull) the heterodermis remains a continuous, simple, unsegmented layer of tissue, and gradually enlarges into a thin-walled capsule enclosing the brain, the primordial skull. In the trunk-half the provertebral

plate divides into a number of homogeneous, cubical, successive planes; these are the several primitive vertebrae. They are not numerous at first, but soon increase as the embryo grows larger (Figs. 153-155).

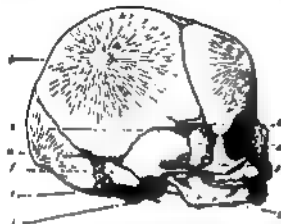


FIG. 153.—Skull of a new-born child. (From *Stemmer*.) *Labels:* a, the three horns of the roof of the skull; b, c, the two large horns of the skull; d, the three horns of the skull; e, the three horns of the skull; f, the three horns of the skull.

In all the Crustacea the soft, undifferentiated cells of the mesoderm, which originally occupy the skeletal plate, are afterwards converted for the most part into cartilaginous cells, and thus become a firm and elastic intercellular substance between them, and form cartilaginous tissue. Like most of the other parts of the skeleton, the overabundant rudiments of the vertebrae soon pass into a cartilaginous state, and in the higher Vertebrates this is afterwards replaced by the hard osseous tissue with its characteristic stellate cells (Fig. 6). The primary axial skeleton remains a simple chorda throughout life in the Acornia, the Cyclostomes, and the lowest fishes. In many of the other Vertebrates the chorda is more or less replaced by the cartilaginous tissue of the secondary perichorda that grows round it. In the lower Crustacea (especially the fishes) a more or less considerable part of the chorda is preserved in the bodies of the vertebrae. In the mammals it disappears for the most

part. By the end of the second month in the human embryo the chorda is merely a slender thread, running through the axis of the thick, cartilaginous vertebral column (Figs. 18a ch. 329 ch.). In the cartilaginous vertebral bodies themselves,

which afterwards ossify, the slender remnant of the chorda permanently disappears (Fig. 339 ch.). But in the elastic intervertebral disks, which develop from the skeletal plate between each pair of vertebral bodies (Fig. 329 h), a relic of the chorda remains permanently. In the new-born child there is a large pear-shaped cavity in each intervertebral disk, filled with a gelatinous mass of cells (Fig. 331 a). Though less sharply defined, this gelatinous nucleus of the elastic cartilaginous disks persists throughout life in the mammals, but in the birds and most reptiles the last trace of the chorda disappears. In the subsequent ossification of the cartilaginous vertebrae the first deposit of bony matter ("first osseous nucleus") takes place on the vertebral body immediately round the remainder of the chorda, and soon displaces it altogether. Then there is a special osseous nucleus formed in each



FIG. 154.—Sagittal section of a primitive fish. *Labels:* a, small part of the vertebral column; b, the first of the vertebral column; c, the first of the vertebral column; d, the first of the vertebral column; e, the first of the vertebral column; f, the first of the vertebral column.

half of the vertebral arch. The ossification does not reach the point at which the two halves are joined until after birth. In the first year the two osseous halves of the arch unite; but it is much longer—in the second—in the eighth year—

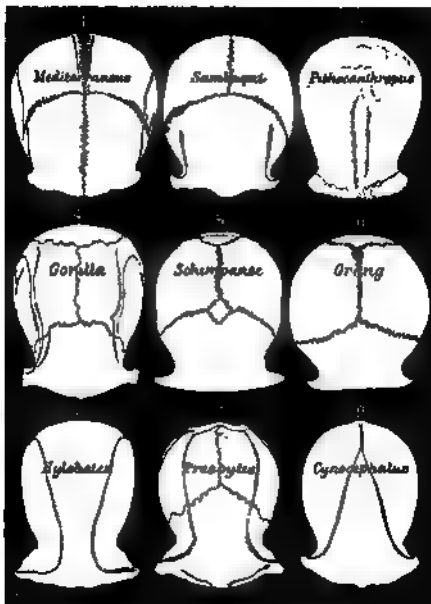


FIG. 229.—Depth of the skull of nine Primates (Colobinae), with lines above and referred to a common size. 1. *Meditarraneus*, 2. *Samitropus*, 3. *Pithacanthropus*, 4. *Gorilla*, 5. *Schimpansen*, 6. *Orang*, 7. *Hylobates*, 8. *Protopithecus*, 9. *Cynocephalus*.

that they connect with the various vertebral bodies.

The bony skull (*cranium*), the head-part of the accessory axial skeleton, develops in just the same way as the vertebral column. The skull forms a bony envelope for the brain, just as the vertebral canal does for the spinal cord; and as the brain is only a peculiarly differentiated part of the head, while the spinal cord represents the longer transsection of the originally homogeneous medullary tube, we shall expect to find

much above. The other thirteen bony parts: the facial skull, which is especially the bony envelope of the higher sense-organs, and at the same time encloses the entrance of the alimentary canal. The lower jaw is articulated at the base of the skull (usually regarded as the XXI. cranial house). Behind the lower jaw we find the hyoid bone at the root of the tongue, also formed from the gill-arches, and a part of the lower arches that have developed as "head-ribs" from the ventral side of the base of the cranium.



FIG. 324.

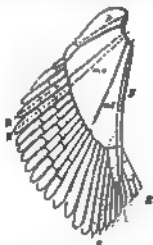


FIG. 325.

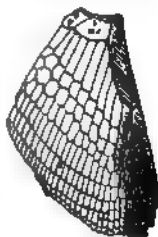


FIG. 326.

FIG. 324.—Skull of the brain-rib of a Canadian beaver (Castor canadensis). A, A, cartilaginous spines of the brain-rib; B, the brain-rib. (From Gaudin.)

FIG. 325.—Skull of the brain-rib of a young teleost fish. The right of the median (A) and the left (B) are designated for the most part as free ribs (A, free ribs; B, free ribs of the dorsal fin-rib, or teleost rib). C, the brain-rib; D, the brain-rib. (From Gaudin.)

FIG. 326.—Skull of the brain-rib of a young teleost fish. The ribs of the upper fin-rib are designated as free ribs (A) and the ribs of the lower fin-rib as teleost ribs (B). C, the brain-rib; D, the brain-rib. (From Gaudin.)

that the osseous coat of the one is a special modification of the osseous envelope of the other. When we examine the adult human skull in itself (Fig. 332), it is difficult to conceive how it can be merely the modified form of the vertebral column. It is an elaborate and extensive bony structure, composed of no less than twenty bones of different shapes and sizes. Seven of these form the spacious shell that surrounds the brain, in which we distinguish the solid ventral base below and the curved dorsal

Although the fully-developed skull of the higher Vertebrates, with its peculiar shape, its enormous size, and its complex composition, seems to have nothing in common with the ordinary vertebrae, nevertheless even the older comparative anatomists came to recognize at the end of the eighteenth century that it is really nothing else originally than a series of modified vertebrae. When Goethe in 1790 "picked up the skull of a slain victim from the mud of the Jewish cemetery at Vienna, he noticed at once

that the bones of the fins also could be traced to vertebrae (like the three hindmost cranial vertebrae)." And when Oken (without knowing anything of Goethe's discovery) found at Bamberg "a fine bleached skull of a fish, the thought flashed across him like lightning: 'It is a vertebral column.'"

This famous vertebral theory of the skull has interested the most distinguished zoologists for more than a century: the chief representatives of comparative anatomy have devoted their highest powers to the solution of the problem, and the interest has spread far

amongst skulls, and had compared the several bones that compose it with the several parts of the vertebra (Fig. 133); they thought they could prove in this way that the fully-formed mammalian skull was made of from three to six vertebrae.

The older theory was refuted by simple and obvious facts, which were first pointed out by Huxley. Nevertheless, the fundamental idea of it—the belief that the skull is formed from the head-part of the perichordal axial skeleton, just as the trunk is from the single sombulatory tube, by differentiation



FIG. 130



FIG. 131



FIG. 132

FIG. 130.—Skeleton of the fore-leg of an amphibia. A separate description of every bone is not given, only bones of first order (radius, ulna, femur, tibia, fibula, metacarpus, metatarsus, phalanx) are shown. (From Gegenbaur.)

FIG. 131.—Skeleton of a bird's hind-leg. (From Huxley.)

FIG. 132.—Skeleton of human hand, hind. (From Huxley.)

beyond their circle. But it was not until 1872 that it was happily solved, after seven years' labour, by the comparative anatomist who surpassed all other experts of his science in the second half of the nineteenth century by the richness of his empirical knowledge and the acuteness and depth of his philosophic speculations. Carl Gegenbaur has shown, in his classic *Studies of the Comparative Anatomy of the Vertebrates* (third edition), that we find the most solid foundation for the vertebral theory of the skull in the head-skeleton of the *Seiche*. Earlier anatomists had wrongly started from the

and modification—retained. The work now was to discover the proper way of supplying this philosophic theory with an empirical foundation, and it was reserved for Gegenbaur to achieve this. He first opened out the phylogenetic path which leads most conveniently to the goal. He showed that the primitive fishes (Figs. 240-251), the ancestors of all the Gnathostomes, still preserve permanently in the form of their skull the structure out of which the test-formed skull of the higher Vertebrates, including man, has been evolved. He further showed that the

branchial arches of the *Salpædæ* prove that their skull originally consisted of a large number of (at least nine or ten) wauvertebrae, and that the cerebral nerves had proceed from the base of the brain entirely confirm this. These cerebral nerves are (with the exception of the first and second pair, the olfactory and optic nerves) merely modifications of spinal nerves, and are essentially similar to them in their peripheral expansion. The comparative anatomy of these cerebral nerves, their origin and their expansion, furnishes one of the strongest arguments for the new vertebral theory of the skull.

We have not space here to go into the details of Gegenbaur's theory of the

each side—the primitive upper jaw (*as palato-quadratum, a*) and the primitive lower jaw (*a*); *IV*, the hyaloid bone (*II*); finally, *V-X*, six branchial arches in the narrower sense (*III-VIII*). From the anatomic features of these nine to ten cranial ribs or "lower vertebral arches" and the cranial nerves that spread over them, it is clear that the apparently simple cartilaginous primitive skull of the *Salpædæ* was originally formed from so many (at least nine) *anterior* or *provertebrae*. The blending of these primitive segments into a single capsule is, however, so ancient that, in virtue of the law of curtailed heredity, the original division seems to have dis-

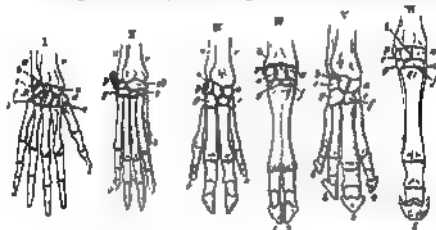


FIG. 332.—Sketches of the head or face that of an annelid. *I* Ann. *II* dog. *III* pig. *IV* cat. *V* tiger. *VI* horse. *a* Palpus. *b* Antenna. *c* Labrum. *d* Labellum. *e* Labium. *f* Mandible. *g* Maxilla. *h* Ventrals. *i* Ventrals. *j* Ventrals. *k* Ventrals. *l* Ventrals. *m* Ventrals. *n* Ventrals. *o* Ventrals. *p* Ventrals. *q* Ventrals. *r* Ventrals. *s* Ventrals. *t* Ventrals. *u* Ventrals. *v* Ventrals. *w* Ventrals. *x* Ventrals. *y* Ventrals. *z* Ventrals. (From Gegenbaur.)

skull, I must be content to refer the reader to the great work I have mentioned, in which it is thoroughly established from the empirico-philosophical point of view. He has also given a comprehensive and up-to-date treatment of the subject in his *Comparative Anatomy of the Vertebrates* (1861). Gegenbaur indicates as original "cranial ribs," or "lower arches of the cranial vertebrae," at each side of the head of the *Salpædæ* (Fig. 332), the following pairs of arches: *I* and *II*, two lip-cartilages, the anterior (*a*) of which is composed of an upper piece only, the posterior (*b*) from an upper and lower piece; *III*, the maxillary arches, also consisting of two pieces on

each side; in the embryonic development it is very difficult to detect it in isolated traces, and in some respects quite impossible. It is claimed that several (three to six) traces of provertebrae have been discovered in the anterior (pre-chordal) part of the *Salpædæ*-skull; this would bring up the number of cranial arches to twelve or thirteen, or even more.

In the primitive skull of man (Fig. 323) and the higher Vertebrates, which has been evolved from that of the *Salpædæ*, five consecutive sections are discoverable at a certain early period of development, and we are induced to trace them to five primitive vertebrae; but these sections are due entirely to adaptation to



FIG. 247.

FIG. 248.

FIG. 249.

FIG. 247.—Leg and foot of *Sturn vulgaris*. FIG. 248.—*Chrysomitris tristis*.
 FIG. 249.—Leg and foot of *Sturn vulgaris*. (From Peck and
 Peck, 1890.)

the five primitive cerebral vesicles, and correspond, like them, to a large number of vertebrae. That we have in the primitive skull of the vertebrate a greatly modified and transformed organ, and not at all a primitive formation, is clear from the circumstance that its original soft membranous form only assumes the cartilaginous character for the most part at the base and the sides, and remains membranous at the roof. At this part the bones of the subsequent osseous skull develop an actual coverings over the membranous structures, without an intermediate cartilaginous stage, as there is at the base of the skull. Thus a large part of the cranial bones develop originally as covering laminae from the surface, and only secondarily come into close touch with the primitive skull (Fig. 331). We have previously seen how this very rudimentary beginning of the skull in man is formed ontogenetically from the "head-plates," and thus the form and of the chorda is enclosed in the base of the skull. (Cf. Fig. 323 and pp. 134, 144, 306 app.)

The phylogeny of the skull has made great progress during the last three decades through the joint labors of comparative anatomy, ontogeny, and paleontology. By the judicious and comprehensive application of the phylogenetic method (in the sense of Gegenbaur) we have found the key to the great and important problems that arise from the thorough comparative study of the skull. A newer school of research, the school of what is called "exact craniology" (so the name of Virchow), has, moreover, made fruitful efforts to obtain this result. We may gratefully acknowledge all that this descriptive school has done in the way of accurately describing the various bones and measurements of the human skull, as compared with those of other mammals. But the too empirical method that it has articulated in its extensive literature is more dead and sterile tradition with it is riveted and illumined by phylogenetic speculation.

Virchow confined himself to the most careful analysis of large numbers of human skulls and bones of anthropoid mammals. He saw only the differences between them, and sought to express them in figures.

Without adducing a single solid reason, or offering any alternative explanation, he referred evolution to us unproved by facts. He played a most unfortunate

part in the controversy as to the significance of the fossil human skulls of Bogy and Mendelthal, and the comparison of them with the skull of the Pithecanthropus (Fig. 353). All the interesting features of these skulls that clearly indicated the transition from the anthropoid to the man were declared by Virchow to be chance pathological variations. He said that the roof of the skull of Pithecanthropus (Fig. 335, 3) must have belonged to an ape, because so pronounced an *orbital structure* (the horizontal constriction between the outer edge of the eye-orbit and the temple) is not found in any human being, immediately after and. Nothing showed in the skull of a Brazilian Indian (Fig. 335, 2), found in the Savanah of Bahia, that the structure can be even deeper in man than in many of the apes. It is very



FIG. 331.—Transverse section of a fish's skull, from the vertex. (From Gegenbaur's *System*.) A, upper jaw; B, lower jaw; C, chorda; D, notochord; E, notochord; F, notochord; G, notochord; H, notochord; I, notochord; J, notochord.

illustrative to this connection to compare the skulls of the skulls (from from above) of different primates. A, then, therefore, arranged them such skulls in Fig. 335, and reduced them to a common size.

We turn now to the branchial arches, which were regarded even by the earlier natural philosophers as "head-ribs." (Cf. Figs. 347-350). Of the four original gill-arches of the vertebrate the first lies between the primitive mouth and the first gill-rib. From the base of this arch is formed the upper-jaw process, which joins with the lower and outer nasal process on each side, in the manner we have previously explained, and forms the chief parts of the skeleton of the upper jaw (palatine bone, pterygoid bone, etc.) (Cf. p. 354). The remainder of the first branchial arch, which is now called, by

way of contrast, the ¹⁴ forms from its base (the hammer and anvil), are converted into a hinge; that is known, after a "Macle's cartilage," or of this

from the cellular

ring of accessory bone, the permanent many lower jaw. From the first part or base of the second branchial arch we get, in the mammalia, the third ossicle of the ear, the stapes; and from the succeeding parts we get (in this order) the malleus of the ear, the styloid process of the

third branchial arch is only cartilaginous at the foremost part, and here the body of the hyoid bone and its larger horns are formed at each side by the fusion of its two halves. The fourth branchial arch is only found transiently in the mammalian embryo as a rudimentary organ, and does not develop special parts, and there is no trace in the embryo of the higher Vertebrates of the posterior branchial arches (fifth and sixth pairs), which are permanent in the Salicid. They have been lost long ago. Moreover, the four gill-slits of the human embryo are only interesting as rudimentary organs, and they soon close up and disappear. The first slote (between the first and second branchial arches) has any permanent significance; from it are developed the tympanic cavity and the Eustachian tube. (Cf. Figs. 169, 326.)

It was Carl Gegenbaur again who solved the difficult problem of tracing the evolution of the limbs of the Vertebrates to a common type. Few parts of the vertebrate body have undergone such infinitely varied modifications in regard to size, shape, and adaptation of structure as the limbs or extremities; yet we are in a position to reduce them all to the same hereditary standard. We may generally distinguish three groups among the Vertebrates in relation to the formation of their limbs. The lowest and simplest Vertebrates, the Actinias and Cyclostomes, had, like their invertebrate ancestors, no pairs of limbs, as we see in the Amphioxus and the Cyclostomes today (Figs. 215, 247). The second group is formed of the two classes of the two fishes and the Elasmobranchs; here there are always two pairs of limbs at first, in the shape of twenty-four fin-rays per

of twenty-four or four legs, and one pair of belly-fins or hind legs (Figs. 248-250). The third group comprises the four higher classes of Vertebrates—the amphibia, reptiles, birds, and mammals, in these quadrupeds there are at first the same two pairs of limbs, but in the shape of five-toed feet. Frequently the first is wholly accepted (the second is not). But the original stem-form of the group had five toes or fingers before and behind (Figs. 263-264).

The true primitive form of the pairs of limbs they were found in the primitive fishes of the Silurian period, is preserved for us in the *Aspidopoma* deposit, the remarkable *Crinoid* (Fig. 257). Both the belly-fin and the belly-fin are flat oval plates, in which we find a dorsal cartilaginous skeleton (Fig. 258). This consists, firstly, of a much exaggerated second or "main" (A. B.), which runs through the fin from base to tip; and secondly of a dorsal row of thin articulated fin-rays (C, D), which are stretched on both sides of the broad, flat, fan-like fin, which Gegenbaur first recognized, is attached to the vertebral column by a single bone in the shape of a cartilage.

It has probably originated from the

the more or less preserved in the fossilized remains of the earliest Salicid (Fig. 252), *Goniatites* (Fig. 253), and *Dipnema* (Fig. 254). It is also found in modified form in some of the actual sharks and fishes. But in the majority of the Salicid it has already degenerated to the extent that on each on one side of the fin-ray have been partly or entirely lost, and are retained only on the other (Fig. 257). Thus we get the unilateral fin, which has been found from the Salicid to the rest of the fishes (Fig. 258).

Gegenbaur has shown how the second hind leg of the Amphibia, that has been

¹⁴ While Gegenbaur states that the fin-ray is a permanent structure, and that they have been modified into a pair of originally unpaired lateral fin-rays.

¹⁵ The fin of the four higher classes is confined to the fin-ray, and the fin-ray is the only part of the fin that is not modified into a pair of originally unpaired lateral fin-rays.

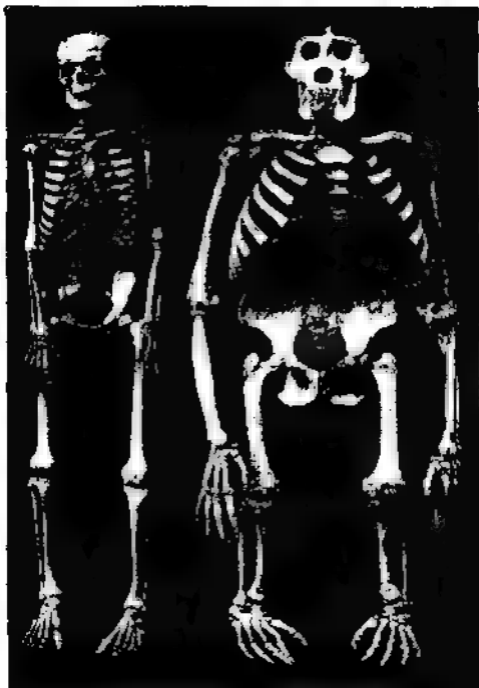


FIG. 347.

FIG. 348.

FIG. 347—Human skeleton. (CL Fig 346)

FIG. 348—Skeleton of the same person. (CL Fig 347)

In the different members of the Amphibia the limbs gradually atrophy, and are lost, for the most part, on the other side of the dorsal as well as the lighter cartilages in Fig. 136b. Only the four lowest rays (shaded in the illustration) are preserved; and these are the four inner toes of the foot (first to fourth). The fifth or fifth toe is developed from the inner end of the dorsal. From the middle and upper part of the dorsal was developed the long stem of the limb—the important radius and ulna (Fig. 137r and a) and humerus (b) of the higher Vertebrates.

In this way the five-finger foot of the Amphibia, which we first meet in the *Carolinianus* *Stegosauria* (Fig. 136b), and which was inherited from them by the reptiles on one side and the dinosaurs on the other, was formed by gradual degeneration and differentiation from the single and bifid (Fig. 321). The reduction of the limb in this way was accompanied by a further differentiation of the limb. Its development began with the upper and lower limbs, and the formation of the axis of the limb which is composed originally of three limbs before and ended in the higher Vertebrates. The single axis of the original *Stegosauria* divides as such into two an upper (dorsal) limb, the *clavicular limb* (*clavula*) and a lower (ventral) part, the anterior part of the latter forms the *propagula clavicula* (*propagula*), and the posterior part the *carpalium*. In the same way the single axis of the *pubic* joint divides up into an upper (dorsal) part, the *clavicular* (*clavula*), and a lower (ventral) part; the anterior part of the latter forms the *pubic bone* (*os pubis*) and the posterior the *ischial bone* (*os ischii*).

There is also a complete separation between the fore and hind limb in the shark or shark. The fore portion of the limb is supported by a single strong bone—the humerus in the fore, the femur in the hind limb. The second portion consists two bones: in front the radius (*r*) and ulna (*u*), behind the *clav* and *ischii*. KK the *clavicular* in Fig. 136b, 137, 138, 139, 140, 141. The remaining numerous small bones of the wrist (*carpi*) and ankle (*tarsi*) are also gradually arranged in the fore and hind portions, and as are the five bones of the middle-hand (*metacarpus*) and middle-foot (*metatarsus*). Finally, it is the same with the toes themselves, which form a distinct characteristic of the

from a series of bony plates before and behind. We find a complete parallel in all the parts of the fin ray and the hind leg.

When we then turn from comparative anatomy that the division of the human limb is supported of part the same bones, put together in the same way, as the division in the four higher classes of Vertebrates, we may at once infer a common descent of them from a single stem-form. This stem-form was the earliest amphibian that had five toes on each foot. It is particularly the outer parts of the limb that have been modified by adaptation to different conditions. We need only recall the numerous variations they offer within the mammal class. We have the diverging legs of the deer and the strong springing legs of the kangaroo, the climbing feet of the mole and the digging feet of the mole, the fine of the cat and the wings of the bat. It will readily be guessed that these organs of locomotion differ so much in regard to our shape, and special function as can be conceived. Nevertheless, the bony skeleton is substantially the same in every case. In the different limbs we always find the same characteristic bones in essentially the same rigidly homologous position, this is an undeniable proof of the theory of evolution as demonstrated by anatomy can become in any organ of the body. It is true that the division of the limb of the lower vertebrates undergoes many alterations and degenerations before the special adaptations (Fig. 324). Thus we find the first finger or the thumb atrophied in the five-finger (or hand) of the dog (11). It has nearly disappeared in the pig (12); and again (V). In the cat (13) and the dog (14) the second and third are also atrophied, and only the third and fourth are well developed (VI). Nevertheless, all these different fore-limbs, as well as the hind of the ape (Fig. 324) and of man (Fig. 324), were originally developed from a common pentadactyl stem-form. This is proved by the rudiments of the degenerated toes, and by the similarity of the arrangement of the wrist-bones in all the pentadactyl (Fig. 324 a-b).

If we carefully compare the bony skeleton of the human arm and hand with that of the most recent and lowest ape, we find an almost perfect identity. This is especially true of the *clavicular*, the

CHAPTER XXVII.

THE EVOLUTION OF THE ALIMENTARY SYSTEM

The chief of the vegetal organs of the human frame, to the evolution of which we now turn our attention, is the alimentary canal. The gut is the oldest of all the organs of the metazoic body, and it leads us back to the earliest age of the formation of organs—in the first section of the Laurentian period. As we have already seen, the result of the first division of labour among the homogeneous cells of the earliest multicellular animal body, was the formation of an alimentary cavity. The first duty and first need of every organism is self-preservation. This is met by the functions of the nutrition and the covering of the body. When, therefore, in the primitive globular *Monera* the homogeneous cells began to effect a division of labour, they had first to meet this twofold need. One half were converted into alimentary cells and enclosed a digestive cavity, the gut. The other half became covering cells, and formed an envelope round the alimentary tube and the whole body. Thus arose the primary germinal layers—the inner,

modifications, has everywhere essentially the same phylogenetic structure (Figs. 30-35). The elaborate alimentary canal of the higher animals develops ontogenetically from the same simple primitive gut of the *gastrula*.

This germinal theory is now accepted by nearly all biologists. It was first suggested and partly modified by Professor May-Landauer, by whom, three years afterwards (in his essay on the development of the *Mollusca*, 1893) is given the name of *archenteron* to the primitive gut and *blastopore* to the primitive mouth.

Before we follow the development of the human alimentary canal in detail, it is necessary to say a word about the general features of its composition in the fully-developed man. The mature alimentary canal in man is constructed in all its main features like that of all the higher animals, and particularly resembles that of the *Cetartia*, the narrows-nosed ape of the Old World. The animal's face, the mouth, is armed with thirty-two teeth, fixed in rows in the upper and

outer, covering, or animal layer. (Cf. pp. 314-17.)

When we try to construct an animal frame of the simplest conceivable type, that has some such primitive alimentary canal and the two primary layers constituting its wall, we inevitably come to the very remarkable embryonic form of the *gastrula*, which we have found with extraordinary persistence throughout the whole range of animals, with the exception of the unicellulars—in the *Spongia*, *Cnidaria*, *Platodes*, *Vermalia*, *Mollusca*, *Articulata*, *Echinoderms*, *Turkulae*, and *Vertebrata*. In all these stems the *gastrula* recurs in the same very simple form. It is certainly a remarkable fact that the *gastrula* is found in various animals as a larva-stage in their individual development, and that this *gastrula*, though much disguised by ontogenetic

tion is exactly the same as that of the *Cetartia*, and differs from that of all other animals (p. 255). Above the mouth-cavity is the double nasal cavity; they are separated by the palato-wall. But we saw that this separation is not there from the first, and that originally there is a common mouth-nasal cavity in the embryo; and this is only divided afterwards by the hard palate into two—the nasal cavity above and that of the mouth below (Fig. 312).

At the back the cavity of the mouth is half closed by the vertical curtain that we call the soft palate, in the middle of which is the uvula. A glance into a mirror with the mouth wide open will show its shape. The uvula is interesting because, besides man, it is only found in the ape. At each side of the soft palate are the tonsils. Through the curved opening that we find

underneath the soft palate we penetrate into the gullet or pharynx behind the mouth-cavity. Into this opens on either side a narrow canal (the Eustachian tube), through which there is direct communication with the tympanic cavity of the ear (Fig. 320 *a*). The pharynx is continued in a long, narrow tube, the oesophagus (*es*). By this the food passes into the stomach where masticated and swallowed into the gullet also comes, right above, the trachea (*tr*), that leads to the lungs. The nature of the food is regulated by the

the canal; it opens only when the pulpy food passes from the stomach into the intestine. In man and the higher Vertebrates the stomach itself is the chief organ of digestion, and is especially occupied with the solution of the food; this is not the case in many of the lower Vertebrates, which have no stomach, and discharge its function by a part of the gut farther on. The muscular wall of the stomach is comparatively thick; it has externally strong muscles that accomplish the digestive mastication and intrinsically a series

The cartilaginous epiglottis is found only in the mammals, and has developed from the fourth branchial arch of the fish and amphibian. The lungs are found in man and all the mammals, on the right and left in the thoracic cavity, with the heart between them. At the upper end of the trachea there is, under the epiglottis, a specially differentiated part, strengthened by a cartilage, the larynx. This important organ of human speech also develops from a part of the alimentary canal. In front of the larynx is the thyroid gland, which sometimes enlarges and forms goitre.

The oesophagus descends into the thoracic cavity along the vertebral column, behind the lungs and the heart, pierces the diaphragm, and enters the visceral cavity. The diaphragm is a muscular-muscular partition that completely separates the thoracic from the abdominal cavity in all the animals (and there alone). This separation is not found in the Reptiles; there is at first a common breast-belly cavity, the coeloma or pleuro-peritoneal cavity. The diaphragm is formed later on as a muscular horizontal partition between the thoracic and abdominal cavities. It then completely separates the two cavities, and is only pierced by several organs that pass from the one to the other. One of the chief of these organs is the oesophagus. After this has passed through the diaphragm, it expands into the gastric sac in which digestion

See plate.

adult man (Fig. 349) is a long, somewhat expanding on the left into a mass of the stomach (*st*), and narrowing on the right, and passing at the pylorus (*py*) into the small intestine. At that point there is a valve, the pyloric valve (*pv*), between the two sections of

glands, which secrete the gastric juice.

Next to the stomach comes the longest section of the alimentary canal, the middle gut or small intestine. Its chief function is to absorb the peptonized fluid



FIG. 349.—Stomach, duodenum and duodenal loop. *a*, cardia, *b*, fundus, *c*, pylorus, *d*, pyloric valve, *e*, duodenum, *f*, pancreas, *g*, gall-bladder and the gall-duct. (From Meyer.)

mass of food, or the chyle, and it is subdivided into several sections, of which the (next to the stomach) is called the duodenum (Fig. 349 *g*). It is a short, horseshoe-shaped loop of the gut. The glands of the alimentary canal open into it—the liver, the chief digestive gland, that secretes the gall, and the pancreas, which secretes the pancreatic juice. The two glands pour their secretions, the bile and pancreatic juice, close together into the duodenum (*1*). The opening of the gall-duct is of particular physiological importance, as it is the same in all the Vertebrates, and indicates the principal point of the hepatic or trunk-gut (Gastroenteron). The liver, physiologically older than the stomach, is a large gland, rich in blood, in the adult man, immediately under the diaphragm on the left

side, and separated by it from the lungs. The pancreas lies a little farther back and more to the left. The remaining part of the small intestine is so long that it has to coil itself in many folds in order to find room in the narrow space of the abdominal cavity. It is divided into the jejunum above and the ileum below. In the last section of it is the part of the small intestine at which in the embryo the yolk-sac opens into the gut. This long and thin intestine then passes into the large intestine, from which it is cut off by a special valve. Immediately behind this "ileocecal valve" the first part of the large intestine forms a wide, pouch-like structure, the caecum. The stretched end of the caecum is the human rudimentary organ, the



Fig. 32.—Lateral view of the head of a human embryo, 14 days old. The foregut is shown in black. 1, The developing mouth; 2, the developing pharynx; 3, the developing esophagus; 4, the developing stomach; 5, the developing liver; 6, the developing yolk sac.

verruiform appendix. The large intestine (colon) consists of three parts—an ascending part on the right, a transverse middle part, and a descending part on the left. The latter finally passes through an S-shaped bend into the last section of the alimentary canal, the rectum, which opens behind by the anus. Both the large and small intestines are equipped with numbers of small glands, which secrete mucus and other fluids.

For the greater part of its length the alimentary canal is attached to the inner dorsal surface of the abdominal cavity, or to the lower surface of the vertebral column. This fixing is accomplished by means of the thin mesenteric plate that we call the mesentery.

Although the fully-formed alimentary canal is thus a very elaborate organ, and yet in detail it has a simplicity of simple structure.

near every day. The structure has been histologically evolved from the very simple form of the primitive. I find in gastrated-ancestors, and that every gastrated brings before us to-day. We have already pointed out (Chapter IX.) how the coelom of the mammals (Fig. 67) can be reduced to the original type of the coelom, which is now preserved by the coelom of the mollusks (Fig. 35). Like the latter, the human gastrated and that of all other mammals must be regarded as the coelomic reproduction of the phylogenetic form that we call the coelom, in which the whole body is nothing but a double-walled gastric sac.

We already know from embryology the manner in which the gut develops in the embryo of man and the other mammals. From the gastrated is first formed the spherical embryonic vesicle filled with fluid (gastrated, Fig. 106). In the dorsal wall of this the sole-shaped embryonic shield is developed, and on the under-side of this a shallow groove appears in the middle line, the first trace of the lower, secondary alimentary tube. The gastrated becomes deeper and deeper, and its edges bend inwards, and finally form a tube.

As we have seen, this simple cylindrical gut-tube is at first completely closed before and behind in man and in the Vertebrates generally (Fig. 248); the permanent openings of the alimentary canal, the mouth and anus, are only formed later on, and from the outer skin. A mouth-pit appears in the skin in front (Fig. 320-321) and this grows towards the blind fore-end of the cavity of the head-gut (Fig. 321), and at length breaks into it. In the same way a shallow anus-pit is formed in the skin behind, which grows deeper and deeper, advances towards the blind hinder end of the gut, and at last connects with it. There is at first, both before and behind, a thin partition between the external cutaneous pit and the blind end of the gut—the stomatodaeum in front and the ano-

stoma in back; these disappear when the connection below place. Directly in front of the anus-opening the alimentary develops from the hind gut; this is the important embryonic structure

that forms into the placenta in Our Placentals (including man). In this more advanced form the human alimentary canal (and that of all the other mammals) is a slightly bent, cylindrical tube, with an opening at each end, and two appendages growing from its lower wall: the anterior one is the umbilical vesicle or yolk-sac, and the posterior the allantoic or urinary sac (Fig. 195).

The thin wall of this simple alimentary tube and its ventral appendages in fetal, or microscopic examination, is consist of two strata of cells. The inner stratum, lining the entire cavity, consists of larger and darker cells, and is the gut-gland layer. The outer stratum consists of smaller and lighter cells, and is the gut-fibre layer. The only exception is in the cavities of the mouth and anus, because these originate from the skin. The lower part of the mouth-cavity is not provided by the gut-gland layer, but by the stomodæum layer; and its muscular submucosa is provided, not by the gut-fibre, but the skin-fibre, layer. (It is the same with the wall of the small anus-cavity).

If it is asked how these constructed layers of the primitive gut-wall are related to the various tissues and organs that we find afterwards in the fully-developed system, the answer is very simple. It can be put in a single sentence. The epithelium of the gut—that is to say, the internal soft stratum of cells that lines the cavity of the alimentary canal and all its appendages, and is immediately occupied with the processes of nutrition—is derived solely from the gut-gland layer, all other tissues and organs that belong to the alimentary canal and its appendages originate from the gut-fibre layer. From the latter is also developed the whole of the outer envelope of the gut and its appendages; the fibrous connective tissues and the smooth muscles that compose its muscular layer, the cartilages that support it (such as the cartilages of the larynx and the trachea), the blood-vessels and lymph-vessels that absorb the nutritive fluid from the intestine—in a word, all that forms is in the alimentary system besides the epithelium of the gut. From the same layer we also get the whole of the mesentery, with all the organs embedded in it—the heart, the large blood-vessels of the body, etc.

Let us now leave this original structure of the maternal gut for a moment, in

order to compare it with the alimentary canal of the lower Vertebrates, and of those Invertebrates that we have recognized as man's ancestors. We find, first of all, in the lowest Metazoa, the Gastrozoa, that the gut remains permanently in the very simple form in which we find it: unchanged in the paligenetic gastrula of the other animals; it is thus in the Gastrozoa (*Planuladæus*), the Physozoa (*Physalia*), the simplest Sponges (*Siphonæ*), the freshwater Polyps (*Hydra*), and the acellular embryos, other Ctenophora (Figs.



FIG. 195.—Section of embryonic mouth of a planula (*Chironomus* embryo). A diamond-shaped space runs obliquely in each of the quadrangular cells, planula stage in the center. (From Gegenbaur.)

233-234). Even in the simplest forms of the Pluteozoa, the Rhizozoözoa (Fig. 240), the gut is still a simple straight tube, lined with the entoderm; but with the important difference that in this case its single opening, the primitive mouth (*stoma*), has formed a muscular gullet (*oes*) by invagination of the skin.

We have the same simple form in the gut of the lowest Vermalia (*Gastrotricha*, Fig. 242, *Naviculæ*, *Sagitta*, etc.). But in these a second important opening of the gut has been formed at the opposite end to the mouth, the anus (Fig. 243 a).

We see a great advance in the structure of the ventral gut in the remarkable *Helicospirax* (Fig. 243), the sole survivor of the Enteropneust class. Here we have the first appearance of the division of the alimentary tube into two portions that characterize the Chordonia. The fore half, the head-gut (*cephalogaster*), becomes the organ of respiration (branchial gut, Fig. 243 b); the hind half, the trunk-gut (*truncogaster*), alone acts as digestive organ (hepatic gut, d). respiratory branchial gut, the posterior the digestive hepatic gut. In both it develops polygenetically from the primitive gut of the gastrula, and in both the hinder end of the medullary tube covers the primitive mouth to such an extent that the remarkable medullary intestinal duct is formed, the passing communication between the neural and intestinal tubes (*canalis oesophageus*, Figs. 82, 85 *nr.*). In the vicinity of the closed primitive mouth, possibly in its place, the later

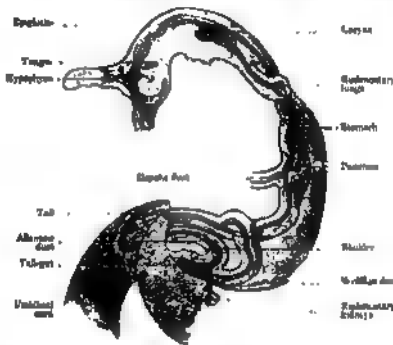


FIG. 243.—Gut of a lampbrush embryo, one-third of an inch long, magnified three times. (From *Atlas*)

The differentiation of these two parts of the gut in the Enteropneust is just the same in all the Terebratulinae.

It is particularly interesting and instructive in this connection to compare the Enteropneusts with the Ascidia and the Amphioxus (Figs. 220, 230)—the remarkable animals that form the connecting link between the Invertebrates and the Vertebrates. In both forms the gut is of substantially the same construction; the anterior section forms the

respiratory organ. In the same way the stomach is a fresh formation in the Amphioxus and the Ascidia.

and that the Ctenostoma generally. The secondary formation of the mouth in the Chordonia is probably connected with the development of the gill-slits which are formed in the gut-wall immediately behind the mouth. In this way the anterior section of the gut is converted into a respiratory organ. I have already pointed out that this modification is distinctive of the

Vertebrates. Hence the original formation of the skeleton of the animals can be traced to these primitive fishes, from which we have inherited it. The teeth are developed from the skin that clothes

it immediately the gut of the earliest Vertebrate (*Gastrotrichus*). It then divides into two sections, a fore or branchial gut and a hind or hepatic gut, like the alimentary canal of the *Hydrozoans*, the *Ascidia*, and the *Amphioxus*. The formation of the jaws and the branchial arches changes it into a real sub-gut (*Splanchnopleur*). But the branchial gut, the one representative of our fish-ancestors, is afterwards atrophied as such. The parts of it that remain are converted into entirely different structures.



FIG. 32.—Section through the head of a *Petromyzon-salmo*. (From Gegenbaur.) A hypobranchial groove below it is the gill slit. To the right is the dorsal opening of the upper pharyngeal pouch, a branchial tube, a branchial vein, a dorsal tube of branchial.

the jaws. As the whole mouth cavity originates from the outer integument (Fig. 32), the teeth also must come from it. As a fact, this is found to be the case on microscopic examination of the development and finer structure of the teeth. The scales of the fishes, especially of the shark type (Fig. 33), are in the same position as their teeth on this respect (Fig. 33). The osseous matter of the tooth (dentine) develops from the ectoderm; its enamel covering is a secretion of the ectoderm that covers the crown. It is the same with the cutaneous teeth or placoid scales of the *Seiichth*. At first the whole of the mouth was covered with these cutaneous teeth in the *Seiichth* and in the earliest amphibians. Afterwards the formation of them was restricted to the edges of the jaws.

Hence our human teeth are, in relation to their original source, modified fish-scales. For the same reason we must regard the salivary glands, which open into the mouth, as epidermic glands, as they are formed, not from the glandular layer of the gut like the rest of the alimentary canal, but from the ectoderm, from the horny plate of the outer germinal layer. Naturally, in harmony with this evolution of the mouth, the salivary glands belong geotically to one series with the sudoriferous, sebaceous, and mucous glands.

Thus the human alimentary canal is as simple as the primitive gut of the *Gastrea* in its original structure. Later

alimentary canal thus entirely loses its original character of branchial gut; it retains the physiological character of respiratory gut. We are now acquainted to this fact the permanent respiratory organ of the higher Vertebrates, the air-breathing lungs, is developed from this first part of the alimentary canal. Our lungs, trachea, and larynx are formed from the ventral wall of the branchial gut. The whole of the respiratory apparatus, which occupies the greater part of the petoral cavity in the adult man, is at first merely a small pair of twicks or tubes, which grow out of the floor of the mouth.



FIG. 33.—Transverse section of the head of a *Petromyzon-salmo*. (From Gegenbaur.) Shows the pharynx (A) and the hypobranchial groove, above it the branchial and dorsal tube. A, B, C stages of construction.

gut immediately behind the gills (Fig. 33, C, 1, 2, 3). These vesicles are found in all the Vertebrates except the two lowest classes, the *Agaric* and *Cyclostomes*. In the lower Vertebrates they do not develop

up, but into a large air-filled bladder, which occupies a good third of the body-cavity and has a quite different purpose. It serves, not the breathing, but to effect swimming movements up and down, and so is a sort of hydrostatic apparatus—the floating bladder of fishes (see *ichthyology*, p. 233). However, the human lungs, and those of all air-breathing Vertebrates, develop from the same simple vesicular appendage of the head-gut that becomes the floating bladder in the fishes.

At first this bladder has no respiratory function, but merely acts as hydrostatic apparatus for the purpose of increasing or lessening the specific gravity of the body. The fishes, which have a fully-developed floating bladder, can press it together, and thus condense the air it contains. The air also escapes sometimes from the alimentary canal, through an air-duct that connects the floating bladder with the pharynx, and is ejected by the mouth. This lessens the size of the bladder, and so the fish swims heavier and sinks. When it wishes to rise again, the bladder is expanded by releasing the pressure. In many of the Cretaceous fish the wall of the bladder is covered with bony plates as in the *Trinacromerus* (Fig. 254).

This hydrostatic apparatus begins the *Dipsosaurus* to change into a respiratory organ; the blood-vessels in the bladder now no longer move air themselves, but also take air through the air-duct. This process reaches its full development in the Amphibia. In them the floating bladder has turned into lungs, and the air-passage into a trachea. The lungs of the Amphibia have been transmitted to the three higher classes of Vertebrates. In the lowest Amphibia the lungs on either side are still very simple transparent sacs with thin walls, as in the common

—— under the Triton. It still entirely resembles the floating bladder of the fishes. It is true that the Amphibia have two lungs, right and left. But the floating bladder is also double in many of the fishes (such as the early *Ganoids*), and divides into right and left halves. On the other hand, the lung is single in *Ceratodus* (Fig. 257).

In the human embryo and that of all the other Amniotes the lungs develop from the hind part of the ventral wall of the head-gut (Fig. 258). Immediately behind the single structure of the dorsal

gland a vesical groove, the rudiment of a sac, is detached from the gullet. From its slender end a couple of vesicles develop—the simple tubular rudiments of the right and left lungs. They afterwards increase considerably in size, fill the greater part of the thoracic cavity, and take the heart between them. The stage we find that the simple sac has developed into a spongy body of peculiar flesh-like tissue. The originally short connection of the pulmonary sac with the head-gut extends into a long, thin tube. This is the wind-pipe (trachea); it opens into the gullet above, and divides below into two branches which go to the two lungs. In the wall of the trachea



FIG. 258.—Thoracic and abdominal viscera of a human embryo of twelve weeks, natural size. (From Krieger.) The head is upper. Viscera and associated parts are shown. The greater part of the body cavity is taken up with the liver, from the middle part of which the vena and the pulmonary arteries originate. Above the diaphragm, in the middle, is the second heart, to the right and left of it are the two small lungs.

cartilages develop, and these keep it open. At its upper end, under the pharynx, opening the larynx is formed—the organ of voice and speech. The larynx is found at various stages of development in the Amphibia, and continues in the Amniotes in a position to trace the progressive growth of this important organ from the rudimentary structure of the lower Amphibia up to the elaborate and delicate vocal apparatus in the larynx of man and of the birds.

—— refer here to an interesting rudimentary organ of the respiratory gut, the thyroid gland, the large gland in front of the larynx, that lies below the "Adam's

From the duodenum are developed the two large glands that we have already mentioned—the liver and pancreas. The liver appears first in the shape of two small sacs, that are found in the right and left immediately behind the stomach (Figs. 253, 254 c). In many of the lower Vertebrates they retain separate the a long tube (in the Myxinoideans throughout life, or are only imperfectly joined. In the higher Vertebrates they soon become more or less completely in form a single large organ. The growth of the liver is very brisk at first. In the human embryo it grows so much in the second month of development that in the third it occupies by far the greater part of the body-cavity (Fig. 267). At first the two lobes develop equally; afterwards the left falls for behind the right. In consequence of the asymmetrical development and turning of the stomach and other abdominal viscera, the whole liver is now pushed to the right side. Although the liver does not afterwards grow so disproportionately, it is comparatively larger in the embryo at the end of pregnancy than in the adult. Its weight relatively to that of the whole body is 1 : 36 in the adult, and 1 : 66 in the embryo, a figure it is very important physiologically during embryonic life, it is chiefly concerned in the formation of blood, not so much in the secretion of bile.

Immediately behind the liver a second large internal gland develops from the duodenum. The pancreas or sweetbread. It is wanting in most of the lowest classes of Vertebrates, and is then found in the fishes. This organ is also an outgrowth from the gut.

The last section of the alimentary canal, the large intestine, is at first in the embryo a very simple, short, and straight tube, which opens behind by the anus. It remains thus throughout life in the lower Vertebrates. But it grows considerably in the mammalia, and in various folds, and divides into two portions, the first and larger of which is the caecum, and the second the rectum. At the beginning of the caecum there is a valve (valvula ileocaecalis) that separates it from the small intestine. Immediately behind this there is a sac-like growth, which merges into the caecum (Fig. 267 v). In the placental mammals this is very large, but it

is very small or completely atrophied in the fish-classes. In man, and most of the apes, only the first portion of the caecum is wide; the blind end-part of it is very narrow, and more like in its merely a median-appendage of the former. This "verruiform appendage" is very interesting as a rudimentary organ. The only significance of it in man is that not infrequently a cherry-stone or some other hard and indigestible matter penetrates into its narrow cavity, and by causing its inflammation and suppuration causes the death of children would often. Tubercle has great difficulty in giving a rational explanation of, and attributing to a homologous function, this dreadful appendicula. In our placental mammals this rudimentary organ was much larger and had a useful function.

Finally, we have important appendages of the alimentary tube in the bladder and ureters, which belong to the alimentary system. These urinary organs, acting as reservoirs and sacs for the urine excreted by the kidneys, originate from the innermost part of the alimentary passage. In the Elasmobranchs and Amphibia, in which the allantoic sac first makes its appearance, it remains within the body-cavity, and functions entirely as bladder. But in all the Amniotes it grows far outside of the body-cavity of the embryo, and forms the large embryonic "primitive bladder," from which the placenta develops in the higher mammals. This is lost at birth. But the long stalk or pedicle of the allantoic vesicle, and forms with its upper part the outside urino-allantoic ligament, a rudimentary organ that gives in the shape of a solid string from the vertex of the bladder to the ovary. The lower part of the allantoic pedicle (or the "urethra") remains hollow, and forms the bladder. At first this opens into the last section of the gut in man as in the lower Vertebrates. But there is a valvular, a high valve at both sides and sacculi. That covering the sacculi this valve is only present in the Mammalia, as it is in all the birds, reptiles, and amphibians. In all the other mammals (marsupials and placentals) a transverse partition is afterwards formed, and this separates the urino-genital aperture in front from the mammary opening behind. (Cf. p. 299 and Chapter XXXIX.)

CHAPTER XXVIII.

EVOLUTION OF THE VASCULAR SYSTEM

THE use that we have hitherto made of our biogenetic law will give the reader an idea how far we may trust its guidance in phylogenetic investigation. This differs considerably in the various systems of organs; the reason is that heredity and variability have a very different stage in these systems. While some of them faithfully preserve the original palaeontologic development inherited from earlier animal ancestors, others show little trace of this rigid heredity; they are rather disposed to follow new and divergent comparative lines of development in consequence of adaptation. The organs of the first kind represent the conservative elements in the multicellular state of the human frame, while the latter represent the progressive element. The course of historic development is a result of the competition of the two tendencies, and they must be carefully distinguished.

There is perhaps no other system of organs in the human body in which this is more necessary than in that of which we are now going to consider the obscure development—the vascular system, or apparatus of circulation. If we were to draw our conclusions as to the original features in our earlier animal ancestors solely from the phenomena of the development of this system in the embryo of man and the other higher Vertebrates, we should be wholly misled. By a number of important embryonic adaptations, the chief of which is the formation of an extensive food-yolk, the original course of the development of the vascular system has been so much falsified and curtailed

in higher Vertebrates that

nothing now remains in their embryology of some of the principal phylogenetic features. We should be quite unable to explain these if comparative anatomy and ontogeny did not come to our assistance.

and all the apparatus of

cavities filled with juices or cell-containing fluids. These "vessels" (*vascula*) play an important part in the nutrition of the body. They partly conduct the nutritive and blood to the various parts of the body (blood-vessels); partly absorb from the gut the white chyle formed in digestion (*chyle-vessels*); and partly collect the waste-juices and convey them away from the tissues (lymphatic vessels). With the latter are connected the large cavities of the body, especially the body-cavity, or coelom. The lymphatic vessels conduct both the colourless lymph and the white chyle into the venous part of the circulation. The lymphatic glands act as producers of new blood-cells, and with them is associated the spleen. The centre of movement for the circulation of the fluids is the heart, a strong muscular sac, which contracts regularly and is equipped with valves like a pump. This constant and steady circulation of the blood makes possible the complex metabolism of the higher animals.

But, however important the vascular system may be to the more advanced and larger and highly-differentiated animals, it is not at all so indispensable an element of animal life as is commonly supposed. The older science of medicine regarded the blood as the real source of life. Even in the still prevalent confused notions of heredity the blood plays the chief part. People speak generally of full blood, half blood, etc., and imagine that the hereditary transmission of certain characters "lies in the blood." The incorrectness of these ideas is clearly seen from the fact that in the act of generation the blood of the parents is not directly transmitted to the offspring, nor does the embryo possess blood in its early stages. We have already seen that not only the differentiation of the four secondary germinal layers, but also the first structures of the principal organs in the embryo of all the Vertebrates, take place long before there is any

of this feature these amoeboid plantlike are called "eating cells" (*phagocytes*), and on account of their motile "travelling cells" (*leucocytes*). It has been shown by the discoveries of the last few decades that these leucocytes are of the greatest physiological and pathological consequence to the organism. They can absorb either solid or dissolved particles from the wall of the gut, and carry them to the blood in the chyle; they can absorb and remove unstable matter from the tissues. When they pass in large quantities through the fine pores of the capillaries and accumulate at infected spots, they cause inflammation. They can consume and destroy bacteria, the arrested vehicles of infectious diseases; but they can also transport these venoms. Monera to fresh regions, and so extend the sphere

of their irregularly distributed in the pores of their prosoplasm. The red cells of most of the Vertebrates are elliptical flat disks, and enclose a nucleus of the same shape, they differ a good deal in size (Fig. 108). The mammals are distinguished from the other Vertebrates by the circular form of their biconcave red cells and by the absence of a nucleus (Fig. 1); only a few genera still have the elliptic form inherited from the reptiles (Fig. 2). In the embryos of the mammals the red cells have a nucleus and the power of increasing by cleavage (Fig. 105).

The origin of the blood-cells and vessels in the embryo, and their relation to the germinal layer and tissues, are among the most difficult problems of ontogeny—some obscure questions on which the most divergent opinions are still advanced.



FIG. 10.—Digestive system of the trunk of a chick-embryo. Description same as (FIG. 108). A, anterior end; B, buccal cavity; C, crop; D, duodenum; E, esophagus; F, foregut; G, gizzard; H, hepatic diverticulum; I, intestine; J, jejunum; K, kidney; L, liver; M, mesoderm; N, notochord; O, oral cavity; P, pharynx; Q, quaternary; R, rectum; S, stomach; T, testis; U, uterus; V, ventricle; W, wall; X, xanthine; Y, yolk; Z, zygote.

of infection. It is probable that the sensitive and travelling leucocytes of our invertebrate ancestors have powerfully co-operated for millions of years to the phylogenesis of the advancing animal organization.

The red blood-cells have a much more restricted sphere of distribution and activity. But they also are very important in connection with certain functions of the cranio-organism, especially the exchange of gases or respiration. The cells of the dark red, carbonized or venous blood, which have absorbed carbonic acid from the animal tissues, give this off in the respiratory organs; they receive instead of it fresh oxygen, and travelling about the bright red colour that distinguishes oxygenated or arterial blood. The red colouring matter of the blood (*hem-*

by the most competent scientists. In general, it is certain that the greater part of the cells that compose the venous and those contents come from the mesoderm—in fact, from the gut-layer layer; it was on this account that Beer gave the name of "vascular layer" to this visceral layer of the ectoderm. But other important observers say that a part of these cells come from other germinal layers, especially from the gut-gland layer. It seems to be true that blood-cells may be formed from the cells of the entoderm before the development of the mesoderm. If we examine sections of chickens, the earliest and most familiar subjects of embryology, we find at an early stage the "primitive arteries" we have already described (Fig. 106) in the ventral angle between the epinotus (*Pe*) and hypostoma (*Sp*). The

thin wall of them first vessels of the primitive embryo consist of flat cells (*endothelia* or *vascular epithelia*); the fluid within already contains molecules of red blood-cells; both have been developed from the gut-tube layer. It is the same with the vessels of the germinal area (Fig. 368 v), which lie on the ectodermic membrane of the yolk-mass (*e*). These features are even still more clearly in the transverse section of the dark-embryo in Fig. 152 (p. 141). In this we see clearly how a number of stellate cells proceed from the "vascular layer" and spread in all directions in the "primary body-cavity"—*r* *e*, in the spaces between the germinal layers. A part of these travelling cells come together and line the wall of the larger spaces, and thus form the first vessels, others enter into the cavity, live in the fluid that fills it, and multiply by cleavage—the first blood-cells.

But, besides these mesodermic cells of the "vascular layer" proper, other travelling cells, of which the origin and purpose are still obscure, take part in the formation of blood in the macroblastic Vertebrates (especially fishes). The chief of these are those that Rudolphi has most aptly designated "macocytes." These "eating yolk-cells" are found in large numbers in the food-yolk of the holostei, especially in the yolk-wall—the harder mass of the germinal disk in which the embryonic vascular net is first developed. The nuclei of the macocytes measure ten times as large as the ordinary cell-nucleus, and are distinguished by their

strong capacity for taking colour, or their special richness in chromatin. Their protoplasmic body resembles the stellate cells of *Amoeba* (also *astrocytes*), and behaves just like a rhizopod (such as *Gromia*); it sends out numbers of stellate processes all round, which ramify and stretch into the surrounding food-cells. These variable and very mobile processes, the pseudopodia of the macocytes, serve both for locomotion and for getting food; as in the real rhizopods, they surround the solid particles of food (granules and plates of yolk), and accumulate round their nucleus the food they have received and digested. Hence we may regard them both as eating-cells

(*phagocytes*) and travelling-cells (*leucocytes*). Their lively nucleus divides quickly and often repeatedly, so that a number of new nuclei are formed in a short time; as each fresh nucleus surrounds itself with a mantle of protoplasm, it provides a new cell for the construction of the embryo. Their origin is still much disputed.

Half of the twelve stems of the animal world have no blood-vessels. They make their first appearance in the *Vertebrata*. Their earliest source is the primary body-cavity, the simple space between the two primary germinal layers, which is either a relic of the segmentation-cavity, or is a subsequent formation. Amorphous plan-

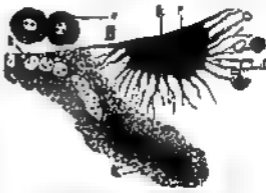


Fig. 368.—Transverse section of a dark-embryo, showing the stellate cells which enter the primary body-cavity (*r*). From Rudolphi's *Physiologie der Thiere*, 1828. The diagram illustrates the process where cells from the vascular layer (v) migrate into the primary body-cavity (r) to form the first blood cells and vessels.

cytes, which migrate from the endothelia and reach this bell-shaped primary cavity, live and multiply there, and form the first colourless blood-cells. We find the vascular system in this very simple form already in the *Bryozoa*, *Rotatoria*, *Nematoda*, and other lower *Vertebrata*.

The first step in the improvement of this primitive vascular system is the formation of larger canals or blood-conducting tubes. The spaces filled with blood, the relics of the primary body-cavity, receive a special wall. "Blood-vessels" of this kind (in the narrower sense) are found among the higher worms in various forms, sometimes very simple, at other times very complex. The first

that was probably the incipient structure of the elaborate vascular system of the Vertebrates (and of the Arthropods) is found in two primordial principal vessels—a dorsal vessel in the middle line of the dorsal wall of the gut, and a ventral vessel close

middle line of it

ventral

dorsal vessel is evolved the aorta (or principal artery), from the ventral vessel the principal or subintestinal vein. The two vessels are connected in front and behind by a loop that runs round the gut. The blood contained in the two tubes is propelled by their peristaltic contractions.

The earliest Vermiform in which we find definite independent vascular system is the Nemertean (Fig. 244). As a rule, they have three parallel longitudinal vessels connected by loops, a single dorsal vessel above the gut, and

right and left. In of the Nemertean the blood is already coloured, and the red colouring matter is real haemoglobin, consisting with elliptical discoid cells, as in the Vertebrates. The further evolution of this rudimentary vascular system can be gathered from the class of the Annelids to which

the Vascular system of Annelids (from Nemertean, a dorsal vessel, a ventral vessel, a subintestinal circulation of the body-wall in relation to heart). The nervous system of the Annelids is of the type of the brain (from dorsal vessel).

we find it at various stages of development. First, a number of transverse connections are formed between the dorsal and ventral vessels, which pass round the gut ring-wise (Fig. 245). Other vessels grow into the body-wall and ramify in order to convey blood to it. In addition to the two large vessels of the middle plane there are often two lateral vessels, one to the right and one to the left; as, for instance, in the leech. There are four of these parallel longitudinal vessels in the Enteropneusts (*Siphonophorus*, Fig. 246). In these important Vermiform the foremost section of the gut

has already been converted into a gill-crease, and the vascular arches that rise in the wall of this the dorsal vessel have become branchial vessels.

We have a further important advance in the Tunicates, which we have recognised as the nearest blood-relatives of our early vertebrates, and

cal heart—i.e., a central organ of circulation, driving the blood into the vessels by the regular contractions of its muscular wall. It is of a very rudimentary character, a spindle-shaped tube, passing at both ends into a principal vessel (Fig. 251). By its original position behind the gill-

s (sometimes a, sometimes less, forward), the heart is clearly that it has been formed by local enlargement of a section of the vent vessel. We have already noticed remarkable abnormality of the direction of the blood stream, the heart driving

Fig. 244. This is very instructive, because most of the worms (even the Enteropneusts) the blood in the dorsal vessel flows from back to front, but in the annelids in the opposite direction. As a *Leech-like* heart abnormality evidently from its direction to the other, it shows unambiguously, in a sense, the physiological position from the earlier forward direction of the dorsal current (in the worms) the new backward direction (in the annelids).



Fig. 244. Head of a flatworm, with rudimentary vascular system. From the left at corner a distal end of the anterior and posterior ventral vessel, or minor ones (enlarged and of C. of the gill-crease (posterior vessel, anterior), of aorta, r. artery, a small gut. (From Gegenbaur.)

specimens that proceed from distal end of the tubular heart acquire a head function.

The foremost section of the ventral vessel henceforth always conveys blood from the heart, and so acts as an artery; the hind section of the same vessel brings the blood from the body to the heart, and so becomes a vein. In view of their relation to the two sections of the gut, we may call the latter the intestinal vein and the former the branchial artery. The blood contained in both vessels, and also in the heart, is venous or carbonized blood—i.e., rich in carbonic acid; on the other hand, the blood the gills into the dorsal vessel is provided with fresh oxygen—arterial or oxygenated blood. The flame branches of the arteries

blood gathers in a ventral vein under the gut (intestinal vein), and goes back to the gills. A number of branchial vascular arches, which effect aspiration and rim in the wall of the branchial gut from belly to back, absorb carbonic acid; they with the dorsal vessel. As the ion of the ventral vessel, which also orates the heart in the Crustacea, has developed in the Ascidia into a simple tubular heart, we may regard the of this to the Amphioxus as a result of degeneration, a return to this more earlier form of the vascular system, i



Fig. 35a.—The ventral arterial arches of the blood system in the Ascidia; a, ventral cross; b, ventral cross; c, ventral cross; d, ventral cross; e, ventral cross; f, ventral cross; g, ventral cross; h, ventral cross; i, ventral cross; j, ventral cross; k, ventral cross; l, ventral cross; m, ventral cross; n, ventral cross; o, ventral cross; p, ventral cross; q, ventral cross; r, ventral cross; s, ventral cross; t, ventral cross; u, ventral cross; v, ventral cross; w, ventral cross; x, ventral cross; y, ventral cross; z, ventral cross.

Fig. 35b.—The ventral arterial arches of the blood system in the Amphioxus; a, ventral cross; b, ventral cross; c, ventral cross; d, ventral cross; e, ventral cross; f, ventral cross; g, ventral cross; h, ventral cross; i, ventral cross; j, ventral cross; k, ventral cross; l, ventral cross; m, ventral cross; n, ventral cross; o, ventral cross; p, ventral cross; q, ventral cross; r, ventral cross; s, ventral cross; t, ventral cross; u, ventral cross; v, ventral cross; w, ventral cross; x, ventral cross; y, ventral cross; z, ventral cross.

Fig. 35c.—The ventral arterial arches of the blood system in the Crustacea; a, ventral cross; b, ventral cross; c, ventral cross; d, ventral cross; e, ventral cross; f, ventral cross; g, ventral cross; h, ventral cross; i, ventral cross; j, ventral cross; k, ventral cross; l, ventral cross; m, ventral cross; n, ventral cross; o, ventral cross; p, ventral cross; q, ventral cross; r, ventral cross; s, ventral cross; t, ventral cross; u, ventral cross; v, ventral cross; w, ventral cross; x, ventral cross; y, ventral cross; z, ventral cross.

and veins pass into each lobe to the lamina by means of a set of very fine, ventral, hair-like vessels, or capillaries (Fig. 35a).

When we turn from the Tunicates to the closely-related Amphioxus we are astonished at first to find an apparent retrogression in the formation of the vascular system. As we have seen, the Amphioxus has no real heart; its colorless blood is driven along in its vascular system by the principal vessel itself, which contracts regularly in its whole length (cf. Fig. 35b). A dorsal vessel that lies above the gut (aorta) receives the arterial blood from the gills and drives it into the body. Returning from here,

and it is many of the assume that the really belong to our ancestral and not the retrogression, but inherited the one-chambered heart of the Prochordonia, and transmitted it directly to the earliest Crustacea (cf. the ideal Primitive Vertebrate, *Amphioxus*, Figs. 93-100).

The further phylogenetic evolution of the vascular system is revealed to us by the comparatively anatomy of the Crustacea. At the lowest stage of this group, in the Cyclostomes, we find for the first time the differentiation of the vasculature into two sections: a system of blood-vessels proper, which convey the red blood about the body, and a system of lymphatic vessels,

which absorb the colourless lymph from the tissues and convey it to the blood. The lymphatics that absorb from the gut and pour into the blood-stream, the milky food-fluid formed by digestion are distinguished by the presence of small fat globules.

While the chyle is a high proportion of fatty particles, the lymph proper is colourless. Both chyle and lymph contain the colourless amoeboid cells (leucocytes, Fig. 22) that we also find distributed in the blood as colourless blood-cells (or "white corpuscles"); but the blood also contains a much larger quantity of red cells, and these give its characteristic colour to the blood of the Crustaceans (rhodocytes, Fig. 32b). The distinction between lymph, chyle, and blood-stem which is found in all the Crustaceans may be regarded as an

advance, the venous blood from the body and passes it on to the anterior section, the ventricle. From this it is driven through the trunk of the branchial artery (the foremost section of the ventral vessel) into the gill-arches.

The Schædil an arterial developed from the foremost end of the ventricle, as a special division, cut off by valves. It passes into the enlarged base of the trunk of the branchial artery (Fig. 363 ab). On each side 2-7 arteries pass out from it. These rise between the gill-closets (g) on the gill-arches, surround the gill-tub, and unite above into a common trunk-aorta, the continuation of which over the gut corresponds to the dorsal vessel of the worms. As the curved arteries on the gill-arches spread into a network of respiratory capillaries, the



FIG. 37-40.—Metamorphosis of the two arterial trunks in the trunk of Crustaceans. In arterial trunk, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000.

outcome of division of labour between various sections of our originally simple vascular system. In the Crustaceans, the spleen makes its first appearance, an organ rich in blood, the chief function of which is the extensive formation of new colourless and red cells. It is not found in the Acrania and Cyclostomes, or any of the Invertebrates. It has been transmitted from the earliest fishes to all the Crustaceans.

The heart also, the central organ of circulation in all the Crustaceans, shows an advance in structure in the Cyclostomes. The simple, spindle-shaped heart-tube, found in the same form in the embryos of all the Crustaceans, is divided into two sections or chambers in the Cyclostomes, and these are separated by a pair of valves. The hind section, the auricle,

receives the venous blood in its lower part (as arches of the branchial artery) and arterial blood in the upper part (as arches of the aorta). The junctions of the various aortic arches on the right and left are called the roots of the aorta. Of an originally large number of aortic arches there remain at first six, then (owing to degeneration of the fifth arch) only five pairs; and from these five pairs (Fig. 356) the chief parts of the arterial system develop in all the higher Vertebrates.

The appearance of the lungs and the atmospheric respiration connected therewith, which we first meet in the Dipneusts, is the next important step in vascular evolution. In the Dipneusts the auricle of the heart is divided by an incomplete partition into two halves. Only the right

receiving the venous blood from the body. The left auricle receives the arterial blood from the pulmonary veins. The two auricles have a common opening into the single ventricle,



FIG. 31



FIG. 32

FIG. 31.—Heart of a rabbit-embryo, from behind. 1, ventricle; 2, auricle of the lungs; 3, auricle of the body; 4, arterial bulb; 5, base of the three pairs of arterial arches. (From Huxley.)

FIG. 32.—Heart of the same embryo (FIG. 31, from the front). 1, ventricle; 2, auricle of the lungs; 3, auricle of the body; 4, arterial bulb; 5, base of the three pairs of arterial arches. (From Huxley.)

where the two kinds of blood

mix or bulk into the arterial arches. From the last arterial arches the pulmonary arteries arise (FIG. 365 p). Thus, for a part of the mixed blood into the lungs, the other part of it going through the aorta into the body.

From the Dipneusta upwards we now trace a progressive development of the vascular system, which ends finally with the loss of branchial respiration and a complete separation of the two halves of the circulation. In the *Amphibia* the partition between the two auricles is complete. In their earlier stages, as tadpoles (FIG. 263), they have still the branchial respiration and the circulation of the fishes, and their heart contains venous blood alone. Afterwards the lungs and pulmonary vessels are developed, and henceforth the ventricle of the heart contains mixed blood. In the reptiles the ventricle and its arterial cone begin to divide into two halves by a longitudinal partition, and this partition becomes complete in the higher reptiles and birds on the one hand, and the stem-forms of the mammals on the other. Henceforth, the right half of the heart contains only venous, and the left half only arterial, blood, as we find in all birds and mammals. The right auricle receives the carbonised or venous blood from the veins of the body, and the right ventricle discharges

through the pulmonary arteries into the lungs. From here the blood returns, as oxygenated or arterial blood, through the pulmonary veins to the left auricle, and is forced by the left ventricle into the arteries of the body. Between the pulmonary arteries and veins is the capillary system of the small or pulmonary circulation. Between the body-arteries and veins is the capillary system of the large or body-circulation. It is only in the two highest classes of Vertebrates—the birds and mammals—that we find a complete division of the circulations. Moreover, this complete separation has been developed quite independently in the two classes, as the structural formation of the aortas shows of itself. In the birds the right half of the fourth arterial arch has become the permanent arch (FIG. 365). In the mammals this has been developed from the left half of the same fourth arch (FIG. 366).

If we compare the fully-developed arterial system of the various classes of animals, we find a good deal of variety, yet it always proceeds from the fundamental type. Its development



FIG. 33



FIG. 34

FIG. 33.—Heart and head of a frog, from behind. 1, ventricle; 2, auricle of the lungs; 3, auricle of the body; 4, arterial bulb; 5, base of the three pairs of arterial arches. (From Huxley.)

FIG. 34.—Heart of the same embryo, from behind. 1, ventricle; 2, auricle of the lungs; 3, auricle of the body; 4, arterial bulb; 5, base of the three pairs of arterial arches. (From Huxley.)

just the same in even as in the other macrozoa; in particular, the modification of the six pairs of arterial arches is the same in both (FIGS. 367-370). At first there is only a single pair of arches, which

lie on the inner surface of the first pair of gill-arches. Behind this there then develop a second and third pair of arches (lying on the inner side of the second and third gill-arches, Fig. 363). Finally, we



FIG. 371.—Heart of a human embryo, two weeks old. *d*, dorsal vessel; *v*, ventral vessel; *g*, gill-arches; *a*, aortic bulb; *l*, left ventricle; *r*, right ventricle; *o*, outflow tract; *u*, superior vena cava; *u*, inferior vena cava; *u*, outflow tract of the inferior vena cava. (From Koller.)

FIG. 372.—Heart of a human embryo, four weeks old. *d*, dorsal vessel; *v*, ventral vessel; *g*, gill-arches; *a*, aortic bulb; *l*, left ventricle; *r*, right ventricle; *o*, outflow tract; *u*, superior vena cava; *u*, inferior vena cava; *u*, outflow tract of the inferior vena cava. (From Koller.)

FIG. 373.—Heart of a human embryo, eight weeks old. *d*, dorsal vessel; *v*, ventral vessel; *g*, gill-arches; *a*, aortic bulb; *l*, left ventricle; *r*, right ventricle; *o*, outflow tract; *u*, superior vena cava; *u*, inferior vena cava; *u*, outflow tract of the inferior vena cava. (From Koller.)

get a fourth, fifth, and sixth pair. Of the six primitive arterial arches of the Aneurysms three soon pass away (the first, second, and fifth), of the remaining three, the third gives the caudate, the fourth the aorta, and the sixth (number 5 in Figs. 364 and 365) the pulmonary arteries.

The human heart also develops in just the same way as that of the other mammals (Fig. 374). We have already seen the first rudiments of its embryology, which in the main corresponds to its phylogeny (Figs. 364, 365). We saw that the polygenetic form of the heart is a spindle-shaped thickening of the god-father layer in the ventral wall of the head-gut. The structure is then hollowed out, forms a simple tube, detaches from its place of origin, and henceforth lies freely in the cardiac cavity. Presently the tube bends into the shape of an S, and turns slightly on an imaginary axis in such a way that

the hind part comes to lie on the dorsal surface of the fore part. The united ventricular veins open into the posterior end. From the anterior end spring the aortic arches.

This first structure of the human heart, enclosing a very simple cavity, corresponds to the tunicate-heart, and is a reproduction of that of the Prochordata, but it now divides into two, and subsequently into three, compartments; this resembles us for a time of the heart of the Cyclostomes and fishes. The spiral turning and bending of the heart increases, and at the same time two transverse constrictions appear, dividing it externally into three sections (Figs. 371, 372). The foremost section, which is turned towards the ventral side, and from which the aortic arches rise, reproduces the auricular bulb of the Schizochord. The middle section is a simple ventricle, and the hindmost, the caudal, turned towards the dorsal side, into which the flowing veins issue, is a simple auricle (or atrium). The latter forms, like the simple atrium of the fish-heart, a pair of lateral dilatations, the

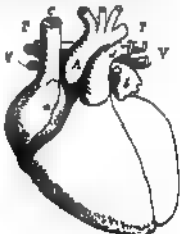


FIG. 374.—Heart of the adult human, fully developed. *d*, dorsal vessel; *v*, ventral vessel; *g*, gill-arches; *a*, aortic bulb; *l*, left ventricle; *r*, right ventricle; *o*, outflow tract; *u*, superior vena cava; *u*, inferior vena cava; *u*, outflow tract of the inferior vena cava. (From Koller.)

auricles (Fig. 371 *b*); and the constriction between the atrium and ventricle is called the auricular canal (Fig. 371 *cn*). The heart of the human embryo is now a complete fish-heart.

In perfect harmony with its phylogeny, the embryonic development of the human heart shows a gradual transition from the fish-heart, through the amphibian and reptile, to the mammal form. The most important point in the transition is the formation of a longitudinal

septum, which

divides the heart into right (venous) and left (arterial) halves (cf. Figs. 373-375). The separate right and left halves, each of which receives blood from the body-veins (upper and lower vena cava, Figs. 373 & 377 c); the left auricle receives the pulmonary veins. In the inferior vena cava

The heart of all the Vertebrates belongs originally to the hypostoma of the head, and we accordingly find it in the embryo of man and all the other Amniotes right in front on the under-side of the head; just as in the fishes it remains permanently in front of the gullet. It afterwards

moves, with the

ventral part of the

trunk, and at last reaches the breast, between the two lungs. At first it is symmetrically in the middle of the body, so that its long axis corresponds

to the axis of the body. But in the Apes the axis begins to be oblique, and the apex of the heart to move towards the left side. The dis-



FIG. 376.—Transverse section of the head of the head of a chick-embryo, forty hours old. (From Müller's *Embryology*, 1st ed., p. 100, fig. 100.) The heart is shown in the ventral part of the head, below the gullet, and is connected with the gullet by the pulmonary artery. The gullet is shown in the dorsal part of the head, and is connected with the heart by the pulmonary vein. The brain is shown in the dorsal part of the head, and is connected with the gullet by the cerebral artery. The diagram illustrates the spatial relationship between these organs in the early stages of development.

further is soon seen in the ventricle (Fig. 376 c). This is the external sign of the internal partition by which the ventricle is divided into two—a right venous and left arterial ventricle. Finally a longitudinal partition is formed in the dorsal section of the primitive fish-like heart, the arterial bulb, externally indicated by a longitudinal furrow (Fig. 376 c). The cavity of the bulb is divided into two internal halves, the pulmonary-artery bulb, that opens into the right ventricle, and the aorta-bulb, that opens into the left ventricle. When all the partitions are complete, the small (pulmonary) circulation is distinguished from the large (body) circulation; the motive centre of the former is the right half, and that of the latter the left half, of the heart.

placement is greatest in the amphipod, apes—chimpanzee, gorilla, and orang—which resemble man in this.

As the heart of all Vertebrates is originally, in the light of phylogeny, only a local enlargement of the middle principal vein, it is in perfect accord with the biogenetic law that its first structure in the embryo is a simple spindle-shaped tube in the ventral wall of the head-gut. A thin mesotheca, standing vertically in the middle plane,

if of the head-gut with the upper head-wall. As the head-gut enlarges and detaches from the gut-wall, it divides the mesotheca into an upper (dorsal) and lower (ventral) plate (usually called the *mesocardium dorsum* and *ventrum* in man, Fig. 379 a, b, c). The

pericardium at its two lateral cavities, Ramm's "neck-cavities" (Fig. 339 A). These cavities afterwards join and form the simple pericardial cavity, and are therefore called by Kützing the "primitive pericardial cavities."

The double cervical cavity of the Arthropods is very interesting, both from the anatomical and the evolutionary point of view; it corresponds to a part of the hypocoelom of the head of the lower Vertebrates—that part of the ventral coelom-pouch.

Wilhe's "visceral cavities" below. Each of the cavities still communicates freely behind with the two coelom-pouches of

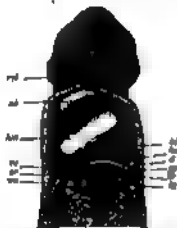


FIG. 340.—Frontal section of a stomach of a grasshopper, showing at each side in the wall, ventral and dorsal coelom, "covered" by *Amphibolus*. The two transverse walls, and ventro-lateral wall, are covered by the *Amphibolus*, and the dorsal wall of the stomach, and the dorsal part of the ventral wall, are covered by the *Amphibolus*. At left lateral part of mass, *Amphibolus*, of diaphragm, or superior transverse wall, or ventral wall, or dorsal wall, or dorsal duct.

(the trunk; and, just as these afterwards coalesce into a simple body-cavity (the ventral mesentery disappearing), we find the same thing happening in the head. This simple primary pericardial cavity has been well called by Gegenbaur the "head-coelom," and by Eberwig the "pericardial breast-cavity." As it now encloses the heart, it may also be called *cardiac*.

The cardiac, or head-coelom, is often disproportionately large in the Arthropods, the simple cardiac tube growing considerably and lying in several folds. This causes the ventral wall of the coelom to contract between the head and the ventral

to be pushed outwards as in rupture (cf. Fig. 340 A). A transverse fold of the ventral wall, which receives all the ventral ducts that open into the heart, grows up from below between the pericardium and the stomach, and forms a transverse partition, which is the first structure of the primary diaphragm (Fig. 340 A). This important muscular partition, which completely separates the thoracic and abdominal cavities in the mammals alone, is still very imperfect here; the two cavities still

are. These canals, which belong to the dorsal part of the head-coelom, and which we may call briefly *pleural ducts*, are the two pulmonary ones, which develop from the hind end of the ventral wall of the head-gut; they thus become the two pleural cavities.

The diaphragm makes its first appearance in the class of the Amphibii (in the salamanders) as an insignificant muscular transverse fold of the ventral wall, which lies from the fore end of the transverse abdominal muscle, and grows between the pericardium and the liver. In the reptiles (turtles and crocodiles) a later dorsal part is joined to this earlier ventral part of the rudimentary diaphragm, a pair of subvertebral muscles rising from the vertebral column and being added as "coeloms" to the transverse partition. But it was especially in the Permian sauro-morphs that the two originally separate parts were united, and the diaphragm became a complete partition between the thoracic and abdominal cavities in the mammalogy; so it considerably enlarges the chest-cavity when it contracts, it becomes an important respiratory muscle.

The ontogeny of the diaphragm in man and the other mammals reproduces this phylogenetic process to-day, in accordance with the biogenetic law, in all the mammals the diaphragm is formed by the secondary conjunction of the two originally separate structures, the earlier ventral part and the later dorsal part.

Sometimes the blending of the two diaphragmatic structures, and consequently the severance of the one pleural duct from the abdominal cavity, is not completed in man. This leads to a diaphragmatic rupture (*hernia diaphragmatica*). The two cavities then remain in communication by an open pleural duct, and loops of the intestine may penetrate by this "rupture opening" into the chest-cavity. This is one of three

fatal mis-growth that show the great part that blind chance has in organic development.

Thus the thoracic cavity of the mammalia, with its important contents, the heart and

apex.

heart is double, as a whole, in all the Animatea, and the simple spindle-shaped cardiac tube, which

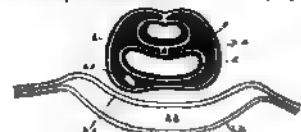


FIG. 31.—Transverse section of the head of a white-eel, showing the heart and surrounding the respiratory tube the top process of the head capsule.

lung belongs originally to the head-part of the vertebrate body, and its inclusion in the trunk is secondary. This unobtrusive and very interesting fact is entirely proved by the concordant evidence of comparative anatomy and ontogeny. The lungs are outgrowths of the head-gut; the heart develops from its inner wall. The pleural sacs that adjoin the lungs are dorsal parts of the head-coelom, originating from the pleural ducts; the pericardium in which the heart afterwards lies is also double originally, being formed from ventral halves of the head-coelom, which

only combine at a later stage. When the lung of the air-breathing Vertebrates issues from the head-cavity and enters the trunk-cavity, it follows the example of the floating bladder of the fishes, which also originates from the pharyngeal wall in the shape of a small pouch-like outgrowth, but soon grows so large that, in order to find room, it has to pass far behind into the trunk-cavity. To put it more precisely, the lung of the quadruped retains this hereditary growth-process of the fishes; for the hydrostatic floating bladder of the latter is the air-filled organ from which the air-breathing organ of the e has been evolved.

There is an interesting ontogenetic phenomenon in the formation of the heart

bryo develops and detaches from the embryonic vesicle that the separate lateral structures join together, and finally combine in the middle line. As the median partition between the right and left cardiacal diaphragms, the two coracal cavities freely communicate (Fig. 381), and later, on the ventral side of the axonotome bend, a horseshoe-shaped arch, the pieces of which advance backwards into the pleurocoelom or pleural cavities, and from there into the two perihomaxial sacs of the trunk. But even after the communication of the coracal cavities (Fig. 382) the two cardiac tubes remain separate



FIG. 32.—Transverse section of the anterior region of the head of a white-eel, showing the heart and surrounding the respiratory tube the top process of the head capsule. (In the ventral part of the heart (12) is well covered by a membrane (14) with the granular layer (15) of pericardial layer, of pericardial space, a corresponding secondary cavity in the thoracic space, 16 and 17 of the anterior side. [From Huxley.]

at first; and even after they have united a delicate partition in the middle of the simple endothelial tube (Figs. 379 & 382) indicates the original separation. This ontogenetic "primary cardiac sep-

turn" presently disappears, and has no relation to the subsequent permanent partition between the halves of the heart, which, as a heritage from the region, has a great palaeogenetic importance.

Thorough opponents of the biogenetic law have laid great stress on these and similar ontogenetic phenomena, and endeavoured to urge them as striking disproofs of the law. As in every other instance, careful, discriminating, comparative-morphological examination converts these supposed disproofs of evolution into strong arguments in its favour. In his excellent work, *On the Structure of the Heart in the Amphibia* (1884), Carl Abel has shown how easily these curious ontogenetic facts can be explained by the secondary adaptation of the embryonic

structure to the great extension of the food-pipe.

The embryology of the other parts of the vascular system also gives us abundant and valuable data for the purposes of phylogeny. But as one needs a thorough knowledge of the intricate structure of the whole vascular system in man and the other Vertebrates in order to follow this with profit, we cannot go into it further here. Moreover, many important features in the ontogeny of the vascular system are still very obscure and controverted. The characters of the embryonic circulation of the Amniotes, which are here previously considered (Chapter IV.), are also acquiritions, and entirely ontogenetic. (Cf. pp. 170-171, Figs. 248-252.)

CHAPTER XXIX.

EVOLUTION OF THE SEXUAL ORGANS

If we measure the importance of the systems of organs in the animal frame according to the richness and variety of their phenomena and the physiological interest that this implies, we must regard as one of the principal and most interesting systems the one which we are now going to examine—the system of the reproductive organs. Just as nutrition is the first and most urgent condition for the self-maintenance of the individual organisms, so reproduction alone secures the maintenance of the species—or, rather, the maintenance of the long series of generations which the totality of the organic stem represents in their genealogical connection. No individual organism has the prerogative of immortality. To each is allotted only a brief span of

million-year course of the of life.

Hence, reproduction and the correlative phenomenon, heredity, have long been regarded, together with nutrition, as the most important and fundamental functions of living things, and it has been attempted to distinguish them from "lifeless bodies" on this very score. As a

matter of fact, this division is not so profound and thorough as it seems to be, and is generally supposed to be. If we examine carefully the nature of the reproductive process, we soon see that it can be reduced to a general property that is found in inorganic as well as organic bodies—growth. Reproduction is a nutrition and growth of the organism beyond the individual limit, which passes a part of it into the whole. This is most clearly seen when we study it in the simplest and lowest organisms, especially the Monera (Figs. 226-228) and the unicellular Amœbæ (Fig. 27). There the simple individual is a single plantlet. As soon as it has reached a certain limit of size by continuous feeding and normal growth, it cannot pass it, but divides, by

Each of these half-independent life, and it soon reaches the limit of growth, and divides. In each of these acts of self-clearance two new centres of attraction are formed for the particles of bodies, the foundations of the two new-formed individuals. There is no such thing as immortality even in these unicellular

The individual we speak is assimilated in the act of cleavage (cf. p. 24).

In many other Protista reproduction takes place not by cleavage, but by budding (gemmation). In this case the growth that determines reproduction is not total (as in conjugation), but partial. Most of generation also we may regard the local growth-product, that becomes a new individual in the bud, as a child-organism to the parent-organism from which it is formed. The latter in order and longer than the former in cleavage the two products are equal in size and morphological value. Next to gemmation we have, as other forms of asexual reproduction, the forming of embryonic buds and the budding of embryonic cells. But the latter buds as a rule in asexual gemmation, the distinctive feature of which is the separation of the parts. I have dealt fully in a (now various) types of reproduction in my *History of Protista* (chap. vi.) and my *Elements of Life* (chap. 2).

The earliest ancestors of man and the higher animals had no faculty of asexual reproduction, but multiplied solely by sexual means—cleavage, germination, or the formation of embryonic buds or cells, as many Protista still do. The differentiation of the sexes came at a later stage. We see this most plainly in the *Proton*, in which the union of two individuals produces the continuous cleavage of the unicellular organism (infusorian conjugation and permanent copulation of the *Infusoria*). We may say that as this first step (the condition of reproduction) is attained in the combination of two fertilizing cells into a single, disproportionately large individual. At the same time the mixture of the two protoplasmic masses a separation of the parts. As soon as the fertilizing cells are quite heterogeneous, but without selection some steps almost a marked contrast between them—larger female cells (*macrogametes*) and smaller male cells (*microgametes*). It was a great advantage in the struggle for life for the two individuals to have inherited different qualities from the two parental parents. The further advance of the contrast between the gametizing cells led to sexual differentiation. One cell became the female ovum (*macrogamete*), and the other the male sperm-cell (*microgamete*).

The simplest forms of sexual reproduction among the living Monera can now be traced to the *Conjunctiva* (p. 23). The latter

organism, the common dark-water jelly (*Hydra*), and other *Conjunctiva* of the lowest rank. *Prothyma* (Fig. 23), *Ophryotrocha* (Fig. 23), *Hydra*, etc., have very simple tubular bodies, the thin wall of which consists (as in the ordinary *gemmae*) only of the two primary germinal layers. As soon as the body reaches sexual maturity, a number of the cells in its wall become female ova, and others male sperm-cells: the former become very large, as they accumulate a considerable quantity of yolk-granules in their cytoplasm (Fig. 23); the latter are very small at present of their required cleavage, and change into minute unsexed sperm-cells (Fig. 23). Such bands of cells detach from their source of origin, the primary germinal layers, fall either into the surrounding water or into the cavity of the gut, and union there by being together. This is the reproductive process of fertilization, which we have examined in the smooth Chapter III (p. 23).

From these simplest forms of sexual propagation, as we see above, that on-day in the lowest *Conjunctiva*, the *Conjunctiva*, *Hydra*, and *Hydra*, we gather most important facts. In the first place, we learn that properly speaking, nothing is required for sexual reproduction except the union or conjugation of two different cells—a female ovum and male sperm-cell. All other features, and all the very complex phenomena that accompany the sexual act in the higher animals, are of a secondary and secondary character and are later additions to this simple primary process of conjugation and fertilization. But if we bear in mind how extremely important a part the union of the two sexes plays in the whole of organic nature, in the life of plants, of animals, and of man, how the sexual attraction of the sexes, here, is the maintaining of the most venerable process—in fact, one of the most mechanical means of the highest development of life—we cannot too greatly emphasize the tracing of love to its source, the attractive force of two sexual cells.

Throughout the whole of living nature the greatest effects proceed from this very small cause. Consider the part that flowers, the sexual organs of the flowering plants, play in nature, or the continuation of wonderful phenomena that sexual selection produces in animal life; or the

never... influence of love in the life of man. In every case the fusion of two cells is the sole original motive power; in every case this invisible process profoundly affects the development of the most varied structures. We may say, indeed, that no other organic process is compared to it for a more pronounced and intensity of a

not the Semitic myth of Adam and Eve, the old Greek legend of Paris and Helena, and so many other famous traditions, only the poetic expression of the vast influence that love selection have exercised upon history, ever since the other

other pass

agitate the heart

tripped in their joint influence by the sense-influencing and mind-harmonizing force. On the one hand, we look to love with gratitude as the source of the greatest artistic achievements—the noblest creations of poetry, plastic art, and music; we see in it the chief factor in the moral advance of humanity, the foundation of family life, and therefore of social advance. On the other hand, we dread it as the devouring force that brings destruction on us easily, and has caused more misery, rape, and crime than all the other sins of human life put together. So wonderful is love and so tremendous its influence on the life of the soul or on the different functions of the voluntary body, that here more than anywhere else the “supernatural” realm seems to reach its attempt at natural explanation. Yet comparative evolution leads us clearly and indubitably to the first source of love: affinity of two different erotic cells, the sperm-cell and ovum.

The lowest Metazoa throw light on this very simple origin of the extreme phenomena of reproduction, and they also teach us that the earliest sexual form was hermaphroditic, and that the separation of the sexes (by division of labour) is a secondary and later phenomenon.

“...aphrodisia... produce... most varied groups of the low sex... usually-mature individual, each person, contains female and male sexual cells, and is therefore able to fertilize itself and reproduce. Thus we find out

and sperm-cells in the same individual, not only in the lowest Zoophytes (Coelenterata, Sponges, and many Polyps), but also in many worms (leeches and earth-worms), many of the invertebrates and many of the vertebrates, and even in man. All

the Coelenterata up to the Anthozoa, were hermaphroditic, possibly even the earliest Acrasids. Here an instructive proof of this

remarkable... general of fishes are still hermaphroditic, and that it is occasionally found in the higher Vertebrates of all classes (as eels). We may conclude from this that gonochorism (separation of the sexes) was a later stage in our development. At first, male and female individuals differ only in the possession of one or other kind of gonads; in other respects they were identical, as we still find in the Amphioxus and the Cyclostomes. Afterwards, accessory organs (ducts, etc.) are associated with the primary sexual glands; and much later again sexual selection has given rise to the secondary sexual characters—those differences between the sexes which do not affect the sexual organs themselves, but other parts of the body (such as the man's beard or the woman's breast).

The third important fact that we learn from the lower Zoophytes relates to the earliest origin of the two kinds of sexual cells. As in the Coelenterata (the lowest sponges and hydroids), in which we find the first beginnings of sexual differentiation, the whole body contains merely of

coated from the cells of these primary layers, either the inner or outer, or from both. This simple fact is extremely important, because the first trace of the ovum as well as the spermatozoon is found in the middle germinal layer or mesoderm in the higher animals, especially the Vertebrates.

development from... section with the secondary formation of the mesoderm.

If we trace the phylogeny of the sexual organs in our ancient Metazoa, especially

of the lowest Coelenterata (Cnidaria, Pluteolaria) exhibit it to us, we find that the first step in advance is the localization or concentration of the two kinds of sexual

attained in the epithelium
the Sponges and

low

detached &

vary germinal layers, and become free
in the Cnidaria and
Platodes we find those associated in
groups which we call sexual glands
(gonads). We can now for the first
time speak of sexual organs in the mor-
phological sense. The female germinative
glands, which in this class have the form
merely groups of homogeneous cells,
the ovaries (Fig. 241 C). The male
germinative glands, which also in their
first form consist of a cluster of sper-
matocytes, are the testicles (Fig. 242 A). In
the medusae, which descend, both ontogen-
etically and phylogenetically, from the
more simply organized Polyps, we find
these simple sexual glands sometimes as

that appear at the edge of the primitive
mouth (right and left), as a rule during
gastrulation or immediately afterwards—
the important protosoblasts, or "polar
cells of the mesoderm," or "primitive
cells of the middle germinal layer" (p.
199). In the real Enterozoa, in which
the mesoderm appears from the first in
the shape of a couple of coelom-pouches,
these are very probably the original
gonads (p. 194). This is seen very clearly
in the arrow-worm (*Sagitta*) in the
gastrula of *Sagitta* (Fig. 351 A) we find
at an early stage a couple of entodermic
cells of an unusual size (*g*) at the base
of the primitive gut (*wt*). These primi-
tive sexual cells (*gonomeres*) are sym-
metrically placed to the right and left of
the midline, like the two protosob-
lasts of the bilateral gastrula of the
Amphioxus (Fig. 35 A p. 66). A little



Fig. 351.—Embryos of *Sagitta*, in three earlier stages of development. (From Huxley.) A gastrula, B with open primary mouth, C the same with primitive mouth closed, as typically seen in primary gastrulae (transverse section). *wt*, the primitive gut; *g*, the gonomeres; *G*, the gonads; *wt*, the ventral layer of the gut; *wt*, the ventral layer of the gut; *wt*, the ventral layer of the gut.

gastric pouches, sometimes as outgrowths of the radial canals that proceed from the stomach. Particularly interesting in connection with the question of the first origin of the gonads are the lowest forms of the Platodes, the *Cryptozoans* that have of late been separated as a special class (*Platodermis*) from the *Turbellaria* proper (Fig. 239). In these very primitive Platodes the two pairs of sexual glands are merely two pairs of rows of undifferentiated cells in the entodermic wall of the primitive gut—two median ovaries (*a*) within, and two lateral spermatocytes (*c*) without. The mature sexual cells are ejected by the posterior outlets; the female (*f*) lies in front of the male (*m*).

In the great majority of the *Platodes* or *Coelenterata* it is the mesoderm from which the gonads develop. Probably the first traces of them are the two large cells

outwards from them the two coelomic pouches (*B, c*) are developed out of the primitive gut, and each protosoblast divides into a male and a female sexual cell (*B, g*). The two male cells (at first rather the larger) lie close together within, and are the parent-cells of the testicles (*gonomeres*). The two female cells lie outwards from these, and are the parent-cells of the ovary (*gonomeres*). Afterwards, when the coelom-pouches have detached from the permanent gut (*G, d*) and the primitive mouth (*A, b*) is closed, the female cells advance towards the mouth (*G, e*), and the male towards the rear. The foremost pair of ovaries are then separated by a transverse partition from the hind pair. Thus the first structure of the sexual glands of the *Sagitta* are a couple of hermaphroditic gonadotropic cells; each of these divides

into a male and a female cell; and these four cells are the parent-cells of the four sexual glands. Probably the two germ-blasts of the Amphioxus-gastrula (Fig. 38) are also hermaphroditic primitive sexual cells in the same sense, inherited by this earliest vertebrate from its ancient bilateral gastrula ancestors.



FIG. 39.—A Part of the Shape of *Balaenoptera*. A. Proventral duct (in *Balaenoptera*). B. Septum of primitive ventral duct (in *Balaenoptera*). C. Septum of *Balaenoptera* septum. D. Part of the septum, highly magnified. E. Septal papilla with the septum, of different artery. F. Different artery. From Johannes Müller (*Myxodonta*).

The sexually-mature *Amphioxus* is not hermaphroditic, as its nearest invertebrate relatives, the Tunicates, are, and as the long-extinct pre-Silurian Primitive Vertebrate (*Prosoponotus*, Figs. 98-100) probably was. The actual lancelet has gonochoristic structures of a very interesting kind. As we saw in the anatomy of the *Amphioxus*, we find the ovaries of the female and the spermaries of the male in the shape of twenty to thirty pairs of elliptical or rounded four-cornered sacs,

which lie on either side of the gut on the parietal surface of the respiratory pore (Fig. 109 g). According to the important discovery of Ruckert (1888), the sexual glands of the earliest fishes, the *Selachii*, are similarly arranged. They only unite afterwards to form a pair of simple gonads. These have been transmitted by heredity to all the rest of the Craniotes. In every case they lie originally on each side of the mesenteric, underneath the chorda, at the bottom of the body-cavity. The first traces of them are found in the coelom-epithelium, at the spot where the skin-fibre layer and gut-fibre layer meet in the middle of the mesenteric plate (Fig. 93 w). At this point we observe at an early stage in all craniote embryos a small string-like cluster of cells, which we may call, with Waldeyer, the "germ epithelium," or (in harmony with the other plate-shaped rudimentary organs) the *sexual plate* (Fig. 173 k). This germinal or sexual plate is found in the 8th week in the human embryo, in the shape of a couple of long whitish streaks, on the inner side of the primitive kidneys (Figs. 183 f). The cells of this sexual plate are distinguished by their cylindrical form and chemical composition from the rest of the coelom-cells; they have a different pigment from the flat cells which line the rest of the body-cavity. As the germ epithelium of the sexual plate becomes thicker, and supporting tissue grows into it from the mesoderm, it becomes a rudimentary sexual gland. This ventral gonad then develops into the ovary in the female Craniotes, and the testis in the male.

In the formation of the gonidia or ovic or spermatocytes and their conjunction or fecundation we have the sole essential features of sexual reproduction; but in the great majority of animals we find other organs taking part in it. The chief of these secondary sexual organs are the gonoducts, which serve to convey the mature sexual cells out of the body, and the copulative organs, which bring the fecundating male sperm into touch with the ovum-bearing female. The latter organs are, as a rule, only found in the higher animals, and are much less widely distributed than the gonoducts. But these also are secondary formations, and are wanting in many animals of the lower groups.

In the lower animals the mature sexual cells are generally ejected directly from

the body. Sometimes they pass out immediately through the skin (Hydra and many hydroids); sometimes they fall into the gastric cavity, and are evacuated by the mouth (gastreaids, sponges, many medusae, and corals); sometimes they pass into the body-cavity, and are ejected by a special pore (*porus genitalis*) in the ventral wall. The latter procedure is found in many of the worms, and also in the lowest Vertebrates. Amphioxus has the peculiar feature that the mature sexual products fall first into the mantle-cavity; from there they are either evacuated by the respiratory pore, or else they pass through the gill-slits into the branchial gut, and so out by the mouth (p. 383). In the Cyclostomes they fall into the body-cavity, and are ejected by a genital pore in its wall; so also in some of the fishes. From them we gather the fact

to convey the sexual products, and this had originally a totally different function—namely, the system of urinary organs. These organs have primarily the sole duty of removing unusable matter from the body in a fluid form. Their liquid excretory product, the urine, is eliminated directly through the skin or through the last section of the gut. It is only at a later stage that the tubular primary passages also convey the sexual products from the body. In this way they become "excretory ducts." This remarkable secondary conjunction of the urinary and sex organs into a common urogenital system is very characteristic of the Cephalosomes, the six higher Phlebobranchs. It is wanting in the lower classes. In order to appreciate it fully, we must give a comparative glance at the structure of the u



1. *Fig.*—Transverse section of the embryonic shell of a shellfish, two-layered shell. (From *Fig. 1* the mantle cavity, *Fig. 2* the mantle cavity, *Fig. 3* the mantle cavity, *Fig. 4* the mantle cavity, *Fig. 5* the mantle cavity, *Fig. 6* the mantle cavity, *Fig. 7* the mantle cavity, *Fig. 8* the mantle cavity, *Fig. 9* the mantle cavity, *Fig. 10* the mantle cavity.)

tures of our earlier ancestors in this respect. On the other hand, in all the higher and most of the lower Vertebrates (and most of the higher Invertebrates) we find in both sexes special tubular passages of the sexual gland, which are called "gonoducts." In the female they conduct the ova from the ovary, and so are called "oviducts," or "Fallopian tubes." In the male they convey the spermatozoa from the testicles, and are called "spermatoducts," or *vasa deferentia*.

The original and generic relation of these two kinds of ducts is just the same in man as in the rest of the higher Vertebrates, and quite different from what we find in most of the Invertebrates. In the latter, as a rule, the gonoducts develop directly from the embryonic glands or from the outer skin; but in the Vertebrates an independent organic system is employed

The renal or urinary system is one of the oldest and most important systems of organs in the differentiated animal body, as I have pointed out on several previous occasions (cf. Chapter XVII.). We find it not only in the higher stems, but also very generally distributed in the entire group of the Vermalia. Here we meet it in the lowest worms, the Rotatoria (*Gastrotrocha*, Fig. 222), and in the instructive stems of the Platyhelminthes. It consists of a pair of simple or branching canals, which are lined with one layer of cells, absorb unusable fluids from the tissue, and eject them by an outlet in the outer skin (Fig. 222 and 223). Not only the free-living Turbellaria, but also the parasitic Suctorians, and even the still more degenerate tapeworms, which have lost their alimentary canal in consequence of their parasitic life, are equipped with these renal canals

throughout life in the Myxinoidea and partly in the Selachii we find the primitive kidney first developing in the embryo of man and the higher Craniotes (Figs. 386, 387). Of the two parts that compose the comb-shaped primitive kidney the longitudinal channel, or nephroduct, is always the first to appear; afterwards the transverse "canals," the excreting nephridia, are formed in the mesoderm; and after this again the Malpighian capsules with their arterial ends are associated with these as caecal outgrowths. The primitive renal duct, which appears first, is found in all craniote embryos at the early stage in which the differentiation of the medullary tube takes place in the ectoderm, the severance of the chorda from the visceral layer in the endoderm, and the first traces of the coelom-pouches arise between the limiting layers (Fig. 386). The nephroduct (*n*) is seen on each side, directly under the horny plate. In the shape of a long, thin, thread-like string of cells. It presently hollows out and becomes a canal, running straight from front to back, and clearly showing in the transverse section of the embryo its original position... the space between horny plates (*h*), primitive septa (*st*), and lateral plates (*lpl*). As the originally very short urinary canals lengthen and multiply, each of the two primitive kidneys assumes the form of a half-feathered leaf (Fig. 387). The lines of the leaf are represented by the urinary canals (*n*), and the rib by the outlying nephroduct (*m*). At the inner edge of the primitive kidneys the rudiment of the ventral sexual gland (*g*) can now be seen as a body of some size. The blademost end of the nephroduct opens right behind into the last section of the rectum, thus making a cloaca of it. However, this opening of the nephroduct into the intestine must be regarded as a secondary formation. Originally they open, as the Cyclostomes clearly show, quite independently of the gut, in the external skin of the abdomen.

In the Myxinoidea the primitive kidneys retain this simple comb-shaped structure,

and a part of it is preserved in the Selachii; but in all the other Craniotes it is only found for a short time in the embryo, as an ontogenetic reproduction of the earlier phylogenetic structure. In those the primitive kidney soon assumes the form (by the rapid growth, lengthening, increase, and serpentine of the urinary canals) of a large compact gland, of a long, oval or spindle-shaped character, which passes through the greater part of the embryonic body-cavity (Figs. 183 *m*, 184 *m*, 388 *m*). It lies near the middle line, directly under the primitive vertebral column, and reaches from the cardiac



Transverse section of a fish embryo, showing the position of the kidney, the gut, the notochord, the ventral sexual gland, the primitive kidney, a double-lobed kidney of a fish, a Wolffian duct (ventral of the right), a dorsal kidney (dorsal), a caecal duct. (From Kükenthal.)

region to the cloaca. The right and left kidneys are parallel to each other, quite close together, and only separated by the secondary—the thin narrow layer that attaches the middle gut to the under surface of the vertebral column. The passage of each primitive kidney, the nephroduct, runs towards the back on the lower and outer side of the gland, and opens in the cloaca, close to the efferent-point of the aorta; it afterwards opens into the aorta itself.

The primitive or primordial kidneys of the cyclostome embryos were formerly called the "Wolffian bodies," and sometimes "Oliver's bodies." They act for a time as

kidneys, absorbing unusable juices from the embryonic body and conducting them to the cloaca—afterwards to the allantois. There the primitive urine accumulates, and thus the allantois acts as bladder or urinary sac in the embryos of man and the other Amniotes. It has, however, no genetic connection with the primitive kidneys, but is a pouch-like growth from the anterior wall of the rectum (Fig. 147 u). Thus it is a product of the ectoderm layer, whereas the primitive kidneys are a product of the middle layer. Physio-

logical wall. It is true that many of the fishes also have a "bladder," but this is merely a local enlargement of the lower section of the nephroducts, and so totally different in origin and composition from the real bladder. The two structures can be compared from the physiological point of view, and so are *analogous*, so they have the same function; but not from the morphological point of view, and are therefore not *homologous*. The tube bladder of the fishes is a mesodermic product of the nephroducts; the true

bladder of the Dipneusta, Amphibia, and Amniotes is an ectodermic blind sac at the rectum.

In all the Acornula (the lower arthropods, insects, Cyclostomes and Amphibia) the urinary organs remain at a lower stage of development to this extent, that the primitive kidneys (protonephridia) per-

sist. This is only so as a passing phase of the early embryonic life in the three higher classes of Vertebrates, the Amniotes. In the permanent or later or (really secondary) kidneys (metanephridia) the direction of

their appearance. They represent the

of the
larval kidneys. The permanent kidneys do not arise (as was long supposed) as independent glands from the alimentary tube, but from the last section of the primitive kidneys and the nephroduct. Here a simple tube, the secondary renal duct, develops, near the point of its entry into the cloaca; and this tube grows considerably forward. With its blind upper or anterior end is connected a glandular renal growth, that owes its origin to a differentiation of the last part of the primitive kidneys. This rudiment of the



Fig. 147 a—Urinary and sexual organs of an embryo. Fig. 147 b—Urinary and sexual organs of an embryo. Fig. 147 c—Urinary and sexual organs of an embryo. (From Müller.)

genetically we must suppose that the allantois originated as a pouch-like growth from the cloaca-wall as consequence of the expansion caused by the urine accumulated in it and excreted by the kidneys. It is originally a blind sac of the rectum. The real bladder of the vertebrate certainly made its first appearance among the Dipneusta (in *Lepidosteus*), and has been transmitted from hibia, and from thence to the embryos of the latter it protrudes far out of the not yet closed

permanent kidneys consists of coiled urinary canals with Malpighian capsules and vascular cells (without coiled funnels), of the same structure as the segmental mesonephridia of the primitive kidneys. The further growth of these metanephridia gives rise to the compact permanent kidneys, which have the familiar bean-shape in man and most of the higher mammals, but consist of a number of separate follicles in the lower mammals, birds, and reptiles. In the permanent kidneys grow rapidly and advance forward. Their passage, the ureter, detaches altogether from its birth-place, the posterior end of the nephroduct; it passes to the posterior surface of the allantois. At first in the oldest Amniotes (the ureter opens into the cloaca together with the last section of the nephroduct, but afterwards separately from this, and finally into the permanent bladder apart from the rectum altogether. The bladder originates from the hindmost and lowest part of the allantoic pedicle (uraceter), which enlarges in spindle shape before the entry into the cloaca. The anterior or upper part of the pedicle, which runs to the tail in the ventral wall of the embryo, atrophies subequally, and only a useless spring-like roll of it is left as a rudimentary organ: that is the single vesico-umbilical ligament. To the right and left of it in the adult man are a couple of other rudimentary organs, the lateral vesico-umbilical ligaments. These are the degenerate string-like relics of the earlier umbilical arteries.

Though in man and all the other Amniotes the primitive kidneys are thus early replaced by the permanent kidneys, and these alone then act as urinary organs, all the parts of the former are by no means lost. The nephroducts become very important physiologically by being converted into the passages of the sexual glands. In all the Gnathostomes—or all the Vertebrates from the fishes up to man—a second similar canal develops beside the nephroduct at an early stage of embryonic evolution. The latter is usually called the Mullerian duct, after its discoverer, Johannes Muller, while the former is called the Wolffian duct. The origin of the Mullerian duct is still obscure; comparative anatomy and ontogeny seem to indicate that it originates by differentiation from the Wolffian duct. Perhaps it would be best to say: "The

original primary nephroduct divides by differentiation (or longitudinal cleavage) into two secondary nephroducts, the Wolffian and the Mullerian ducts." The latter (Fig. 387 m) lies just on the inner side of the former (Fig. 387 w). Both open behind into the cloaca.

However uncertain the origin of the nephroduct and its two products, the Mullerian and the Wolffian ducts, may be, its later development is clear enough. In all the Gnathostomes the Wolffian duct is converted into the spermaduct, and the Mullerian duct into the oviduct. Only one of them is retained in each sex; the other either disappears altogether, or only leaves relics in the shape of rudimentary organs in the male sex,



FIG. 387.—Pelvic region of a *Heterostichus* (Gnathostomus), Fig. 387. *w*, Wolffian duct; *m*, Mullerian duct; *cl*, cloaca. *w* is the Wolffian duct, *m* is the Mullerian duct, and *cl* is the cloaca.

in which the two Wolffian ducts become the spermaducts, we often find traces of the Mullerian ducts, which I have called "Rathke's cords" (Fig. 394 c). In the female sex, in which the two Mullerian ducts form the oviducts, there are relics of the Wolffian ducts, which are called "the ducts of Coertner."

We obtain the most interesting information with regard to this remarkable evolution of the nephroducts and their association with the sexual glands from the Amphibia (Figs. 390-395). The first structure of the nephroduct and its differentiation into Mullerian and Wolffian ducts are just the same in both sexes in the Amphibia, as in the mammal embryos (Figs. 392, 393). In the female Amphibia

the Mullerian duct develops on either side into a large oviduct (Fig. 393 c). While the Wolffian duct acts permanently as a urter (*u*). In the male *Amphibia* the Mullerian duct only remains as a



Fig. 393. — Original position of the sexual ducts in the ventral body of the female embryo (large number 393). (a) shows the Wolffian duct (*u*) and Mullerian duct (*m*). (b) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (c) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (d) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (e) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (f) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (g) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (h) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (i) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (j) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (k) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (l) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (m) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (n) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (o) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (p) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (q) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (r) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (s) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (t) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (u) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (v) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (w) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (x) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (y) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct. (z) shows the Wolffian duct (*u*) and Mullerian duct (*m*) with the oviduct (*o*) developing from the Mullerian duct.

rudimentary organ without any functional significance, as Rathke's canal (Fig. 394 c), the Wolffian duct serves also as urter, but at the same time as spermatid duct, the spermatid duct (*s*) that proceed from the testicles (*t*) carrying the lower part of the primitive kidneys as blasing there with the urinary use.

In the mammals three pairs amphibian features are only seen as brief phases of the earlier period of embryonic development (Fig. 392). Here the primitive kidneys, which act as excretory organs of urine throughout life in the amelon-less Vertebrates, are replaced in the mammals by the permanent kidneys. The real primitive kidneys disappear for the most part at an early stage of development, and only small relics of them remain.

In the male mammal the *epididymus* develops from the uppermost part of the primitive kidney; in the female a useless rudimentary organ, the *epoovarium*, is formed from the same part. The atrophied relic of the former is known as the *paradidymis*, that of the latter as *parooovarium*.

The Mullerian ducts undergo very important changes in the female mammal.

Evidence proper are developed only their upper part; the lower part changes into a spindle-shaped tube with which the *uterus* is connected, in which the *ovum* develops into.

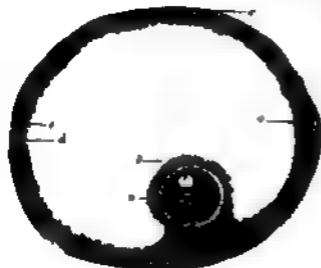
That is the womb (*uterus*). At first the two wombs (Fig. 395 a) are completely separate, and open into the cloaca on either side of the bladder (*u*), as is still the case in the lowest living mammals, the *Monotremes*. But in the *Marsupials* a communication is opened between the two Mullerian ducts, and in the *Placentals* they combine below with the rudimentary Wolffian ducts to form a single "genital cord." The original independence of the two wombs and the vaginal canals formed from their lower ends are retained in many of the lower *Placentals*, but in the higher they gradually blend and form a single organ. The conjunction proceeds from below (or behind) upwards (or forwards) in many of the *Rodents* (such as the rabbit and squirrel) two separate wombs still open into the *myths* and single vaginal canal, but in others, and in the *Carnivora*, *Cetacea*, and *Ungulates*, the



Fig. 395. — Uterine system of a human female. (a) shows the two uteri (u) and vaginas (v). (b) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (c) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (d) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (e) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (f) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (g) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (h) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (i) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (j) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (k) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (l) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (m) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (n) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (o) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (p) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (q) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (r) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (s) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (t) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (u) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (v) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (w) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (x) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (y) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri. (z) shows the two uteri (u) and vaginas (v) with the oviducts (o) developing from the uteri.

lower lobes of the wombs have already fused into a single piece, though the upper lobes (or "horns") are still separate ("two-horned" womb, *uterus bicornis*). In the bats and leopards the "horns" are

original mesonephros, which develops from the lowest section of the bladder (2). But while in the male mammal the Wolffian ducts develop into the permanent sperm ducts, there are only rudimentary relics left of the Müllerian ducts. The most notable of these is the "male womb" (*uterus masculinus*), which originates from the lowest fused part of the ducts, and corresponds to the female uterus. It is a small, flask-shaped vesicle without any physiological significance, which opens into the ureter between the two sperm ducts and the prostatic folds (*prostatea prostatica*).



—1. *Human female*. *a*, the uterus; *b*, the fallopian tube; *c*, the ovary; *d*, the vagina; *e*, the clitoris.

The internal sexual organs of the female undergo very distinctive changes of position. At first the genital glands of both sexes lie deep inside the ventral cavity, at the inner edge of the primitive kidneys (Figs. 385 *a*, 386 *A*), attached to the vertebral column by a short mesentery (*mesonephros* in the male, *mesonephros* in the female). But this primitive arrangement is retained permanently only in the Monotremes (and the lower Vertebrates). In all other mammals (both Marsupials and Placentals) they leave their cradle and travel more or less — (or behind), following the direction of a ligament that goes from the primitive

kidneys to the inguinal region of the ventral wall. This is the inguinal ligament of the primitive kidneys, known in the male as the Hunterian ligament (Fig. 400 *g*), and in the female as the "round maternal ligament" (Fig. 401 *r*). In woman the ovaries travel more or less towards the small pelvis, or enter into it altogether. In the male the testicles pass out of the ventral cavity, and penetrate by the inguinal canal into a sac-shaped fold of the outer skin. When the right and left folds ("scrotal swellings") join together they form the scrotum. The various mammals bring before us the

successive stages of this displacement. In the elephant and the whale the testicles descend very little, and remain underneath the kidneys. In many of the rodents and carnivores they enter the inguinal canal. In most of the higher mammals they pass through this into the scrotum. As a rule, the inguinal canal closes up. When males open it may periodically into the scrotum withdraw into the ventral cavity again.

(*Fig. 402* in =

plat., rodents,

bats, etc.)

The structure of the external sexual organs, the copulative organs that convey the fertilizing sperm from the male to the female organ in the act of

copulation, is also peculiar to the mammals. There are no organs of this character in most of the other Vertebrates. In those that live in water (such as the Acrania and Cyclostomes, and most of the fishes) the ova and sperm-cells are simply ejected into the water, where their conjunction and fertilization are left to chance. But in many of the fishes and amphibians, which are viviparous, there is a direct convey-

— of the male sperm into the female body; and this is the case with all the Amniotes (reptiles, birds, and mammals). In these the urinary and sex-ducts always open originally into the last of the rectum, which thus forms a cloaca.

(p. 349). Among the mammals this arrangement is permanent only in the Monotremes, which take their name from it (Fig. 359 *cf.*). In all the other mammals a frontal partition is developed in the cloaca (in the human embryo about the beginning of the third month), and this divides it into two cavities. The anterior cavity receives the urogenital canal, and is the sole outlet of the urine and the sexual products; the blood or anus-cavity passes the excrement only.

Even before this partition has been formed in the Marsupials and Placentalia,

we see the first trace of the external sexual organs. First a conical protuberance rises at the anterior border of the cloaca-outlet—the sexual prominence (*phallus*, Fig. 402 A, c, B, c.). At the tip it is swollen in the shape of a club ("acorn" *glans*). On its under side there is a furrow, the sexual groove (*furrow genitalis*, f.), and on each side of this a fold of skin, the "sexual pad" (*carus preputialis*, b.). The sexual protuberance or phallus is the chief organ of the sexual sense (*genitalia*); the sexual nerves spread on it, and three are the principal organs of the specific sexual sensation. As *scrotula* bodies (*scrotula preputialis*) are developed in the early phallus by peculiar modifications of the blood-vessels, it becomes capable of erecting periodically as a strong accession of blood, becoming stiff, so as to penetrate into the female vagina and thus effect copulation. In the male the phallus becomes the penis; in the female it becomes the much smaller clitoris; this is only found to be very large in certain apes (*Ateles*). A prepuce ("foreskin") is developed in both sexes as a protecting fold on the anterior surface of the phallus.

The external sexual member (*phallus*) is found at various stages of development within the mammal class, both in regard to size and shape, and the differentiation and structure of its various parts; this applies especially to the terminal part of

the phallus, the glans, both the larger glans penis of the male and the smaller glans clitoridis of the female. The part of the cloaca from the upper wall of which it forms belongs to the proctodaeum, the ectodermic invagination of the rectum (p. 341); hence its epithelial covering can develop the same hairy growths as the cutaneous layer of the epidermis. Thus the glans, which is quite smooth in man and the higher apes, is covered with spines in many of the lower apes and in the cat, and in many of the rodents with hairs (marmoset) or scales (guinea-pig) or

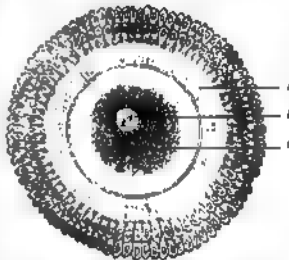


FIG. 402.—The cloaca viewed after tearing from the *Orangia* phallus, according to clearing with the *Alumina* negative (in two related figures). a, central dark spot, the *scrotula* body; b, outer ring of small *scrotula* bodies of the *scrotula*; c, outer *scrotula*; d, outer *scrotula* of the *scrotula* body. (From Hagen, magnified 40 times.) (See Figs. 401 and 403, 404 and 405.)

rodent hairy warts (*verrucae*). Many of the Ungulates have a free conical projection on the glans, and in many of the Ruminantia the "phallus-tentacle" grows into a long cone, bent hook-wise at the base (as in the goat, antelope, gazelle, etc.). The different forms of the phallus are connected with variations in the structure and distribution of the sensory nerves—*s.*, the real organs of the sexual sense, which develop in certain papillae of the corium of the phallus, and have been evolved from ordinary tactile corpuscles of the corium by trophic adaptation (p. 343).

The formation of the anthers anteriorly, which causes the stiffness of the phallus and its capability of penetrating the vagina, by means of special structures of their spermy manner organs, also shows a good deal of variety within the vertebrate class. This stiffness is increased in many orders of mammals (especially the ungulates and rodents) by the condensation of a part of the Skene's gland (*apophysis Skeneana*). This pseudo-testis (*as pengu*) is very large in the badger and dog, and larger than a testis in the marine; it is also very large in some of the lower apes, and provides for exit into the vagina. It is wanting in most of the anthropoid apes; it seems to have been lost in this case (and in man) by atrophy.

The vaginal groove on the under side of the phallus regresses in its width the nearer the uterine canal, and is changed into a constriction of the vagina, becoming a closed canal by the protraction of its parallel edges, the male urethra. In the female this only takes place in a few cases (some of the ungulates, rodents, and whales), as a rule, the groove remains open, and the lumina of this "vestibule of the vagina" develop into the smaller labia (*apophysis*). The large labia of the female develop from the external parts (*the genitalia*) the two parallel folds of the skin that are fused on each side of the genital groove. They join together in the middle, and form the clitoral urethra. There is nothing different between the two main classes yet indicated in the human embryo of the fifth week. We begin to trace them in the tenth week of development, and they are interpreted in proportion to the difference of the sexes developed.

However, the normal position of the two external parts in the male fails to take place, and the vaginal groove may also remain open (*hypospadias*). In these cases the external male genitalia resemble the female, and they are often wrongly regarded as cases of hermaphroditism. Other malformations of various kinds are not infrequently found in the lowest external sexual organs, and some of them have a great morphological interest. The reversal of hypospadias, in which the parts in split open below, is man is *epispadias*, in which the opening is open above. In this case the vaginal canal opens above at the dorsal end of the penis; in the former case down below. These and similar abnormalities interfere

with a man's generative power, and thus profoundly affect his whole development. They clearly prove that our theory is not founded by a "local Providence," but rests on the play of blind chance.

We must carefully distinguish the normal case of real hermaphroditism from the preceding. This is only found when the external organs of reproduction, the genital glands of both kinds, are united in one individual. In these cases either an ovary is developed on the right and a testis on the left (or vice versa); or else there are testicles and ovaries on both sides, some more and others less developed. As hermaphroditism was probably the original arrangement in all the Vertebrates, and the division of the sexes only followed by later differentiation of lines, these earlier cases differ in theoretical difficulty. But they are rarely found in man and the higher mammals. On the other hand, occasionally real hermaphroditism is seen in the lower Vertebrates, such as the *Megachasma*, many fishes of the parrot-fish (*parrotfish*), and some of the Amphibia (winged salamanders). In these cases the male often has a rudimentary ovary at the fore end of the ductile; and the female sometimes has a rudimentary testis or ductile. In the carp also and some other fishes this is found occasionally. We have already seen how terms of the earlier hermaphroditism can be traced in the passages of the Amphibia.

Man has fortunately preserved the main features of his masculinity in the embryology of his organs and sexual organs. We can follow their development step by step in the human embryo in the quite advantageous gradation that is presented to us by the comparison of the uterine organs in the Acrida, Cylindrocephala, Frogs, Amphibia, Reptiles, and then (within the covered series) in the Monotremes, Marsupials, and the various Placental. All the participation of uterine glands structures that distinguished the mammals from the rest of the Vertebrates are found in man; and in all special structural features he resembles the apes, particularly the anthropoid apes. In point of the fact that the special features of the mammals have been inherited by man, I will, in conclusion, point out the blindest way in which the sex are formed in the ovary. In all the mammals the mature sex are contained in special capsules, which are known as the Graafian

follicles, after their discovery, Renger and Graaf (1677). They were formerly supposed to be the ova themselves; but Renger discovered the ova within the follicles (p. 16). Each follicle (Fig. 409) consists of a round fibrous capsule (*d*), which contains fluid and is lined with several strata of cells (*e*). The layer is thickened like a knob at one point (*f*); this ovum-capsule encloses the ovum proper (*a*). The mammal ovary is originally a very simple oval body (Fig. 387 *st*), formed only of connective tissue and blood-vessels, covered with a layer of cells, the ovarian epithelium or the female germ epithelium. From this germ epithelium sprouts of cells grow out into the connective tissue or "stroma" of the ovary (Fig. 402 *st*). Some of the cells of these strings (see Pfliiger's tubes) grow larger and become ova (primitive ova, *c*), but the great majority remain small, and form a protective and nutritive stratum of cells round each ovum—Ova "follicle-epithelium" (*e*).

The follicle-epithelium of the mammal has at first one stratum (Fig. 402 *s*), but afterwards several (*e*). It is true that in all the other Vertebrates the ova are enclosed in a membrane, or "follicle," that consists of smaller cells. But it is only in the mammals that fluid accumulates between the growing follicle-cells, and distends the follicle into a large round capsule, on the inside wall of which the ovum lies, at one side (Figs. 405, 406). Thus again, as in the whole of his morphology, man proves indubitably his descent from the mammals.

In the lower Vertebrates the formation of ova in the germ-epithelium of the ovary continues throughout life; but in the higher it is restricted to the earlier stages, or even to the period of embryonic develop-

ment. In man it seems to cease in the first year; in the second year we find no new-formed ova or oocytes of ova (Pfliiger's tubes). However, the number of ova in the two ovaries is very large in the young girl; these are calculated to be 72,000 in the sexually-mature maiden. In the production of the ova more resembles men of the anthropoid apes.

Generally speaking, the natural history of the human sexual organs is one of those parts of anthropology that furnish the most convincing proofs of the animal origin of the human race. Any man who is acquainted with the facts and impartially weighs them will conclude from them alone that we have been evolved from the lower Vertebrates. The larger and the detailed structure, the action, and the embryological development of the sexual organs are just the same in man as in the apes. This applies equally to the male and the female, the internal and the external organs. The differences we find in this respect between man and the anthropoid apes are much lighter than the differences between the various species of apes. But all the apes have certainly a common origin, and have been evolved from a long-extinct early-Tertiary stem-form, which we must trace to a branch of the fissure. If we had this unknown pithecoid stem-form before us, we should certainly put it in the order of the true apes in the primate system; but within this order we cannot, for the anapleric and omogonetic reasons we have seen, separate man from the group of the anthropoid apes. Here again, therefore, on the ground of the pithecoma-principle, comparative anatomy and ontogeny teach with full confidence the descent of man from the apes.

CHAPTER XXX.

RESULTS OF ANTHROPOGENY

Now that we have traversed the wonderful region of human embryology and are familiar with the principal parts of it, it will be well to look back on the way we have come, and forward to the further path to truth to which it has led us. We started from the simplest facts of embryology, or the development of the individual—facts from observations that we can repeat and verify by microscopic and anatomic study at any moment. The first and most important of these facts is that every man, like every other animal, begins his existence as a single cell. This round cell has the same characteristic form and origin as the ovum of any other animal. From it is developed, in the same manner in all the Placentalia, by repeated cleavage, a multicellular blastula. This is converted into a gastrula, and this in turn into a blastocoel (or embryonic vesicle). The two strata of cells that compose its wall are the primary germinal layers, the skin-layer (ectoderm), and gut-layer (enteroderm). The two-layered embryonic form is the ontogenetic reproduction of the extremely important phylogenetic transformation of all the Metazoa, which we have called the Gastron. As the human embryo passes through the gastrula-form like that of all the other Metazoa, we can trace its phylogenetic origin to the Gastron.

As we continued to follow the embryonic development of the two-layered structure, we saw that first a third, or middle layer (mesoderm), appears between the two primary layers; when this divides into two, we have the four secondary germinal layers. These have just the same composition and genetic significance in man as in all the other Vertebrates. From the skin-sense layer are developed the epidermis, the central nervous system, and the chief part of the sense-organs. The skin-fibre layer forms the corium and the motor organs—the skeleton and the muscular system. From the gut-fibre layer are developed the vascular system, the muscular wall of the gut, and the sexual glands. Finally, the sub-internal

layer only forms the epithelium, or the inner cellular stratum of the mucous membrane of the alimentary canal and glands (lungs, liver, etc.).

The manner in which these different systems of organs arise from the secondary germinal layers is essentially the same from the start in man as in all the other Vertebrates. We saw, in studying the embryonic development of such organs, that the human embryo follows the special lines of differentiation and construction that are only found elsewhere in the Vertebrates. Within the limits of this vast stem we have followed, step by step, the development both of the body as a whole and of its various parts. This higher development follows in the human embryo the form that is peculiar to the mammalia. Finally, we saw that, even within the limits of this class, the various phylogenetic stages that we distinguish as a natural classification of the mammals correspond to the ontogenetic stages that the human embryo passes through in its course of its evolution. We were thus in a position to determine precisely the position of man in this class, and so to establish his relationship to the different orders of mammals.

The line of argument we followed in this explanation of the ontogenetic facts was simply a consistent application of the biogenetic law. In this we have throughout taken strict account of the distinction between paleogenetic and ontogenetic phenomena. Paleogenetic (or "synoptic development") alone enables us to draw conclusions from the observed embryonic facts to the form preserved by heredity. Such inference becomes more or less precarious when there has been convergence, or disturbance of development, owing to fresh adaptations. We cannot understand embryonic development unless we appreciate this very important distinction. Here we stand at the very limit that separates the older and the new science or philosophy of nature. The whole of the results of recent natural history research cannot be irresistibly

to complete the Magnesian we need to be reaching metamorphic. There can be no doubt, however, that the highest and doctrine of former days, that metamorphism is an act of religious education. But without the Magnesian law, without the distinction between paleogenetic and neogenetic, and without the theory of evolution on which we base it, it is quite impossible to understand the facts of organic development: without them we cannot read the latest glacial of explanation over this marvelous field of phenomena. But when we recognize the essential derivation of anatomy and physiology ascribed in this law, the wonderful facts of embryology are put up to us as a very simple explanation: they are found to be the necessary mechanical effects of the evolution of the man, determined by the law of heredity and adaptation. The operative action of these laws under the universal influence of the struggle for existence, or we may say in a word, with Darwin's "natural selection," is entirely adequate to explain the whole process of embryology in the light of physiology. It is the chief merit of Darwin that he explained by his theory of selection (the correlation of the laws of heredity and adaptation that Lamarck had recognized, and pointed out the way to reach a causal interpretation of evolution.

The phenomenon that it is most impossible to recognize in this connection is the inheritance of functional variations. John Lamarck was the first to appreciate its fundamental importance in this, and we may therefore justly give the name of Lamarckism to the theory of descent he based on it. Among the radical opponents of the latter have very properly charged their attacks chiefly against the former. One of the most distinguished and most serious-minded of these opponents, Huxley, has, after very positively that "characteristic acquired in the life of the individual are not inherited."

The inheritance of acquired characters is denied, not only by thorough opponents of evolution, but even by scientists who adopt it and have constructed a grand deal to its establishment, especially Weinmann, Gadow, Ray Lankester, etc. None like the chief opponent has been August Weismann, who has endorsed the greatest service in the development of Darwin's theory of evolution. In his work on *The Continuity of the Genera-*

tion, and in his recent excellent *Lectures on the Theory of Descent* (1902), he has with great success advanced the opinion that "only those characters can be transmitted to successive generations that were contained in rudimentary form in the embryo." However, this gene-glass theory, with its attempt to explain heredity, is merely a "preliminary molecular hypothesis"; it is one of those metaphysical speculations that attribute the evolutionary phenomena exclusively to internal causes, and regard the influence of the environment as insignificant. Herbert Spencer, Theodor Koller, Lester Ward, Huxley, and Lankester have pointed out the inevitable consequences of this position. I have given my view of it in the tenth edition of *The History of Creation* (pp. 194, 195). I hold, with Lamarck and Darwin, that the hereditary transmission of acquired characters is one of the most important phenomena in biology, and is proved by thousands of morphological and physiological experiments. It is an indispensable foundation of the theory of evolution.

Of the many and weighty arguments for the truth of this assumption of evolution I will for the present merely point to the evidence for evolution of embryology, the primordia of rudimentary organs. We cannot deny the value of the strength of the great morphological significance of these rudimentary organs, which are completely useless from the physiological point of view. We find some of them outside parts, inherited from our vertebrate ancestors, in every system of organs in man and the higher vertebrates. Thus we find at once on the skin a cavity and rudimentary part of ear, only fully developed in the hand, under the shoulder, and at a few other parts of the body. The short hairs on the greater part of the body are quite useless and devoid of physiological value. They are the last vestige of the thicker hairy coat of our simian ancestors. The memory apparatus presents a series of most remarkable rudimentary organs. We have seen that the whole of the shell of the external ear, with its cartilage attached, and then, in man a useless appendage, and has all the physiological importance that was formerly ascribed to it. It is the degenerate remnant of the pinna, hairy covering, and mass of cartilage removed, the remains of which we still have, but cannot work them. We found at the

lateral center of our eye a small, medium, semi-linear field that is of no use whatever to us, and is only interesting as the last relic of the retreating membrane, flattened, linear eyelid that had a distinct physiological purpose in the ancient chorion, and still has in many of the Ammians.

The motor apparatus, in both the skeleton and muscular system, provides a number of interesting dysphysiological organisms. I need only recall the prelingual tail of the human embryo, with its rudimentary caudal vertebrae and muscles; this is totally useless in man, but very interesting as the degenerate relic of the long tail of our distant ancestors. From these we have also inherited vertebrae heavy processes and muscles, which were very useful to them in climbing trees, but are useless to us. At various points of the skin we have cutaneous muscles which are never remnants of a strongly-developed cutaneous muscle in our lower mammalian ancestors. This "parietalis carnosus" had the function of contracting and crumpling the skin to draw away the flies, as we see every day in the horse. Another point on us of this large cutaneous muscle is the frontal muscle, by which we look our forehead and turn our eyebrows, but there is another considerable relic of it, the large procerus muscle in the nose (*placoma myxoides*), over which we have no voluntary control.

Not only in the systems of animal nature, but also in the vegetable kingdom, we find a number of rudimentary organs, many of which we have already noted. In the alimentary apparatus there are the thyro-gland and the thyro-gland, the vent of gullet and the relic of a stalked growth that the Turbans and Actinias still have in the gill-venter; there is also the vermiform appendix to the caecum. In the vascular system we have a number of useless vessels which represent relics of atrophied vessels that were once active as blood-vessels—the double *Bailli* between the pulmonary artery and the aorta, the double venous *Bailli* between the portal vein and the vena cava, and many others. The many rudimentary organs in the urinary and sexual apparatus are particularly interesting. These are generally developed in one sex and rudimentary in the other. Thus the *epididymus* are derived from the Wolffian ducts in the male, whereas in the female we have merely rudimentary

traces of them in Gartner's ducts. On the other hand, in the female the ovaries and uterus are developed from the Mullerian ducts, while in the male only the lowest ends of these organs are the "male ducts" (*canaliculi prostatici*). Again, the male has in his sigmoid and rectum glands the rudiments of organs that are usually active only in the female.

A careful scientific study of the human frame would disclose to us numbers of other rudimentary organs, and these can only be explained on the theory of evolution. Robert Huxley has collected a large number of them in his work on *The Human Frame as a Whole as it is*. They are some of the strongest proofs of the truth of the morphological hypothesis and the strongest disproofs of the ontological theory. If on the latter grounds, man or any other organism had been designed and fixed for his purposes from the start and brought into being by a creative act, the existence of these rudimentary organs would be an insupportable enigma; it would be impossible to understand why the Creator had put this useless burden on his creature to walk a path that is in itself so very easy. But the theory of evolution gives the simplest possible explanation of them. It says, "The rudimentary organs are parts of the body that have fallen into disuse in the course of centuries; they had definite functions in our ancestral ancestors, but have lost their physiological significance. On account of their insignificance they have become superfluous, but are nevertheless then preserved to generation by heredity, and gradually atrophy."

We have inherited not only these rudimentary parts, but all the organs of our body, from the mammals—probably from the apes. The human body does not contain a single organ that has not been inherited from the apes. In fact, with the aid of our fingers we can trace the origin of our various systems of organs much further, down to the lowest stages of our ancestry. We can say, for instance, that we have inherited the oldest organs of the body, the external skin and the internal part of the alimentary system, from the Coelenterates; the nervous and vascular systems from the Platyhelminths; the vascular system, the body-cavity, and Oviduct from the Nemertea; the pharynx and the muscular gut from the Protophytes;

the orthologies of the body from the Anaxians; the primitive skull and the higher sense-organs from the Cyclophorians; the lungs and liver from the Sphinctes; the fore-limb from the Amphibia; the palate from the Haploids; the hairy coat, the mammary glands, and the external sexual organs from the Pro-mammals. When we formulated "the law of the ontogenetic succession of systematically related forms," and determined the relative age of organs, we now have it as possible to draw phylogenetic conclusions from the ontogenetic succession of systems of organs.

With the aid of this important key and of comparative anatomy we were also enabled to determine man's place in nature, or, as we put it, assign to man his position in the classification of the animal kingdom. In recent zoological classifications the animal world is divided into twelve main or phyla, and these are broadly subdivided into about sixty classes, and these classes into at least 300 orders. In his true organization man is most properly, in the first place, a member of one of these main, the vertebrate stem; secondly a member of one particular class of this stem, the Mammalia, and thirdly, of one particular order, the order of Primates. He has all the characteristics that distinguish the Vertebrates from the other eleven animal stems, the Mammals from the other sixty classes, and the Primates from the 300 other orders of the animal kingdom. We may have said and said on the line, but we cannot get over this sort of system and classification. On this score the fact has given rise to a great deal of discussion, and especially of controversy as to the particular ontogenetic relationship of man to the ape. The most curious opinions have been advanced on this "ape-question," or "phylogeneticity." It is so well, therefore, to go into it once more and distinguish the material from the immaterial. (KX 286-5, pp. 286-5.)

We start from the universal fact that man is in any case—whether we want to reject his special blood-relationship to the ape—a true mammal; in fact, a placental mammal. This fundamental fact can be proved so easily at any moment from comparative anatomy that it has been universally admitted since the lower mammals (Monophiles and Marsupials). But for every consistent sci-

entist to the theory of evolution it must follow at once that man descends from a common stem-form with all the other Placentalia, the stem-ancestor of the Placentalia. Just as we must admit a common mammal ancestor of all the mammals. This is, however, to pose definitely the great and moving question of man's place in nature, whether or no we go on to admit a nearer or more distant relationship to the ape. Whether man is or is not a member of the ape-order (or, if you prefer, the primate-order) in the phylogenetic sense, in any case his direct blood-relationship to the root of the mammals, and especially the Placentalia, is established. It is possible that the relations of the various orders of mammals to each other are different from what we hypothetically assume today. But, in any case, the common descent of man and all the other mammals from one stem-form is beyond question. This long-erected Pro-mammal was probably evolved from Protomammals during the Triassic period, and must certainly be regarded as the monerous and common ancestor of all the mammals.

If we hold firmly to the fundamental and most important truths we shall see the "ape-question" in a very different light from that in which it is usually regarded. Little reflection is then needed to see that it is not nearly so important as it is said to be. The origin of the human race from a series of ancestral mammals, and the biologic evolution of these from the earlier series of lower vertebrate animals, together with all the weighty conclusions that every thoughtful man deduces therefrom, remain untouched, so far as their own concerned. It is immaterial whether we regard man "ape" or our nearest ancestor is not. But as it has become the fashion to lay the chief stress in the whole question of man's origin on the "descent from the ape," I am compelled to return to it once more, and recall the facts of comparative anatomy and embryology that give a decisive answer to this "ape-question."

The shortest way to settle our position is that followed by Huxley in 1851 in his able work, which I have already often quoted, *Man's Place in Nature*—the way of comparative anatomy and embryology. We have to compare impartially all man's organs with the same organs in the higher apes, and then to perceive if the difference between the two are greater

than the corresponding difference between the higher and the lower apes. The indubitable and incontestable result of this comparative-anatomical study, conducted with the greatest care and impartiality, was the phylogenetic principle, which we have called the Huxleyian law in honor of its discoverer—namely, that the difference in organization between man and the most advanced ape we know are much slighter than the corresponding difference in organization between the higher and lower apes. We may even give a more precise formula to this law, by excluding the Platyrrhini or American apes as *extreme* relatives, and restricting the comparison to the narrower family-circle of the Catarrhini, the apes of the Old World. Within the limits of this small group of mammals we found the structural difference between the lower and higher catarrhine apes—for instance, the baboons and the gorilla—to be much greater than the difference between the anthropoid apes and man. If we now turn to anatomy, and find, according to our law of the ontogenetic construction of systematically related forms,¹ that the embryo of the anthropoid apes and man retain their resemblance for a longer time than the embryo of the higher and the lowest apes, we are forced, whether we like it or no, to recognize our descent from the order of apes. We can scarcely construct an appropriate picture to the visualization of the form of our early Tertiary ancestor from the foregoing facts of comparative anatomy; however we may frame this in detail, it will be the picture of a tree ape, and a distinct catarrhine ape. This has been shown so well by Huxley (1863) that the recent attacks of Kowalev, Virchow, and other anthropologists, have completely failed (cf. pp. 287-288). All the structural characters that distinguish the Catarrhini from the Platyrrhini are found in man. Hence in the genealogy of the mammals we must derive man immediately from the catarrhine group, and locate the origin of the human race in the Old World. Only the early position from which both descended was common to them.

It is, therefore, established beyond question for all impartial scientific inquiry that the human race comes directly from the apes of the Old World; but, on the same claim, I repeat that this is not so important in connection with the entire

question of the origin of man as is commonly supposed. Even if we entirely ignore it, all that we have learned from the ontological facts of comparative anatomy and physiology as to the physical structure of man remains unchanged. These facts beyond all doubt the common descent of man and all the rest of the mammals. Further, the main question is not in the past affected if it is old; "It is true that man is a mammal," but he has diverged at the very root of the stem from all the other mammals, and has no closer relationship to any living group of mammals." The affinity to man or less than in any case, if we assume the division of the mammal stem to the sixty other lines of the animal world. Quite certainly the whole of the mammals, including man, have had a common origin; and it is equally certain that their common ancestors were gradually evolved from a long series of lower Vertebrates.

The reluctance to the theory of a descent from the apes is clearly due in most cases to feeling rather than to reason. They shrink from the nature of such an origin just because they see in the ape organism a caricature of man, a distorted and unattractive image of themselves; because it hurts man's aesthetic appreciation and self-conceitment. It is quite flattering to think we have descended from some lofty and god-like being; and so. Even the worst thing, however, which has been allowed to believe in our origin from gods is dogmatism. The Church, with that emphatic consent of blasé of which it is a master, has succeeded in representing this ridiculous play of vanity as "Christian dogmatism," and the very man who rejects with horror the notion of an animal origin, and names themselves "children of God," love to pride of their "divine essence of intellect." In case of the sciences that have passed out their pulp and bite against the doctrine of evolution because vanity and conceit have been a supernatural descent; and, although we have identified the very characteristic weakness from the apes, we must admit that we have developed it to a higher degree, which is entirely repugnant to reason and natural indignation. We are greatly annoyed at all the childish fictions that the childish pride of vanity has introduced from the Middle Ages to our own time; yet there is a large amount of this empty feeling in

were men. Just as most people would prefer to trace their family back to some distinguished hero or to a famous prince rather than to an unknown peasant, or most men would rather have as parent of the race a noble and fallen Adam than an advancing and vigorous ape. It is a matter of taste, and in that extent we cannot quarrel over these genealogical hypotheses. Personally, the notion of descent is more congenial to me than that of descent. It seems to me a finer thing to be the advanced offspring of a subordinate, than the developed progeny of a subordinate. But the dogmatic descendant of a godlike being, made from a god, and fallen for his sin, and so descended from one of the ribs. Speaking of the ribs, I may add in what I have said about the development of the skeleton, that the number of ribs is just the same in man and woman. In both of them the ribs are formed from the middle germinal layer, and are, from the phylogenetic point of view, lower or unpaired vertebral bodies.

But it is said: "That in all very well, as far as the human body is concerned; but the facts quoted it is impossible to state that it has really and gradually been evolved from the long vertebral series of the Vertebrates. But it is quite another thing as regards man's mind or soul; this cannot possibly have been developed from the vertebrate soul." Let us see if we cannot meet this grave difficulty upon the evolutionary basis of comparative anatomy, physiology, and embryology. It will be best to begin with a comparative study of the skulls of various groups of Vertebrates. Now we find such an enormous variety of vertebrate skulls that, at first sight, it seems quite impossible to trace them all to a common "Primitive Vertebrate." Think of the ray Amphioxus, with no real brain but a simple medullary tube, and the whole perched high at the very lowest stage among the Vertebrates. The following group of the Cyclostomes are still very limited, though they have a brain. When we pass on to the fishes, we find their intelligence remaining at a very low level. We do not see any material advance in mental development until we go on to the Amphibians and Reptiles. There is

still greater advance when we come to the Mammals, though even here the skulls of the Monotremes and of the winged Marsupials remain at a low stage. But when we rise from these to the Placental we find within this one vast group such a number of important stages of differentiation and progress that the psychic differences between the least intelligent (such as the sloth and armadillo) and the most intelligent Placentals (such as the dog and ape) are much greater than the psychic differences between the lowest Placentals and the Marsupials or Monotremes. Most particularly the differences are far greater than the differences in mental power between the dog, the ape, and man. For all these animals are genetically related members of a single natural class.

We see this in a still more striking aspect in the comparative psychology of another class of animals, that is especially interesting for every reason, the insect class. It is well known that we find in many insects a degree of intelligence that is found in man alone among the Vertebrates. Everybody knows of the human characteristics and signs of love and hate, and of the very remarkable social arrangements in them, such as we find among the more advanced forms of man, but seeing no other group of animals I need only mention the social organization and government of the monarchic bees and the republican ants, and their division into different conditions—queen, drone, soldier, worker, soldier, soldier, etc. One of the most remarkable phenomena in this very interesting portion is the caste-living of the ants, which most plentifully as well as most regularly extract their honeyed juice. Still more remarkable is the slave-holding of the large red ants, which send the young of the small black ants and bring them up as slaves. It has long been known that these mutual and social arrangements of the ants are due to the deliberate cooperation of the countless colonies, and that they understand each other. A number of recent observers, especially Fritz Müller, Sir J. Lubbock (Lord Avebury), and August Forel, have put the astonishing degree of intelligence of them far beyond the beyond question.

Now compare with these the mental life of many of the lower, especially the parasite, insects, as Darwin did. There is, for instance, the common house

¹ The English name of the ray is *Amphioxus*, and the Latin name is *Amphioxus*.

(*Chama*), which, in its adult state, has a questionless, shield-shaped body, attached to the lower of phloem. It is then an acrophid. Its anus is open in the same of the pieces of which it abounds the pup. The whole psychic life of these most female parasites consists in the pleasure they experience from sucking the sap of the plant and in sexual intercourse with the male. It is the same with the sugar-beetle females of the family (*Scaphidiidae*), which spend their lives parasitically and harmlessly, without wings or feet, in the abdomen of stings. There is no question now of higher psychic action. If we compare these sluggish parasites with the intelligent and active ants, we must admit that the psychic difference between them is much greater than the psychic difference between the lowest and highest mammals. Between the Monkeys, Apes, and man, on the one hand and the dog, cat, or even the spider. Yet all these groups belong to the same class of Arthropods, just as all the mammals belong to one and the same class. And just as every scientific conclusion must admit a common origin for all these classes, so we must also for the mammals.

If we now turn from the comparative study of psychic life in different animals to the question of the origin of the psychic life, we receive the answer that in all the higher animals they are always bound up with certain groups of cells, the ganglionic cells or neurones that compose the nervous system. All scientists without exception are agreed that the central nervous system is the organ of psychic life in the animal, and it is possible to prove this experimentally in any manner. When we partially or wholly destroy the central nervous system, we extinguish in the same proportion, partially or wholly, the "mind" or psychic activity of the animal. We have, therefore, to discover the function of the psychic organ in man. The reader already knows the insupportable answer to this question. Man's psychic organ is, in structure and origin, just the same organ as in all the other Vertebrates. It originates in the shape of a simple rudimentary tube from the same rudiments of the embryo—the disc-cum-layer. The simple cerebral vesicle that is formed by the expansion of the head-part of this rudimentary tube divides by successive ramifications into five, and then goes through more or less the same stages

of construction in the human embryo as in the rest of the vertebrates. As there are undoubtedly of a common origin, study looks and spinal cord must also have a common origin.

Physiology teaches us further, on the ground of observation and experiment, that the relation of the "mind" to its organ, the brain and spinal cord, is just the same as in all the other vertebrates. The one cannot act at all without the other; it is just as much bound up with it as muscular movement is with the muscles. It can only develop in connection with it. If we are mechanists at all, and grant the usual intuition of consciousness and philosophy, we are forced to admit this thesis: The human mind or psyche, as a function of the medullary tube, has developed along with it, and just as brain and spinal cord now develop from the simple medullary tube in every human body, so the human mind of the psychic life of the whole human race has been gradually evolved from the lower vertebrates and. Just as today the intricate structure of the brain corresponds step by step from the lower rudiments of every human mind was—the same five cerebral vesicles—as in all the other Vertebrates, so the human mind has been gradually developed in the course of centuries of years from a long series of vertebrates. Finally, just as today in every human embryo the various parts of the brain differentiate after the typical type of the vertebrates, so the human psyche has gradually developed from the type and

It is true that the Monistic conception is rejected with horror by most men, and the Dualistic idea, which shows the inseparable connection of brain and mind, and regards body and mind as two totally different things, is still popular. But how can we reconcile this view with the known facts of evolution? It meets with difficulties upon every point and everywhere in embryology and in physiology. If we suppose with the majority of men that the mind is an independent entity, which has nothing to do with the body organically, but merely inhabits it for a time, and gives impetus to its movements through the brain just as the pilot steers through his instrument, we must assign a point in human embryology at which the soul enters into the brain; and at death again we must assign a moment at which it abandons the body. As, further, each human individual has inherited certain

personal features from each parent, we must suppose that in the act of conception pieces were detached from their nuclei and transferred to the oöcytes. A piece of the paternal soul goes with the spermatozoon, and a piece of the mother's soul remains in the ovum. At the instant of conception, when portions of the two souls of the reproducing cells join together to form the nucleus of the zygote, the corresponding fragments of the immaterial souls meet and are supposed to combine.

On this Dualistic view the phenomena of psychic development are easily comprehensible. Everybody knows that the newborn child has no consciousness, no knowledge of itself and the surrounding world. Every parent who has impartially followed the mental development of his children will find it impossible to deny that it is a case of biological evolutionary processes. Just as all other functions of the body develop in connection with their organs, so the soul does in connection with the brain. The gradual unfolding of the soul of the child is, in fact, as wonderful and glorious a phenomenon that every mother or father who has eyes to observe is never tired of contemplating it. It is only our methods of psychology that know nothing of this development. We are almost tempted to think sometimes that their authors can cover their head children themselves. The human soul, as described in most of our psychological works, is merely the soul of a learned philosopher, who has read a good many books, but knows nothing of education, and never even reflects that his own soul has had a development.

When these Dualistic philosophers acknowledge they must accept a material in the physiology of the human soul at which it was first "introduced" into man's vertebrate body. Hence, at the time when the human body was evolved from the anthropoid body of the ape (probably in the Tertiary period), a specific human psychic element—or, as people love to say, "a spark of divinity"—must have been suddenly infused or branched into the anthropoid brain, and been connected with the apesoul already present in it. I need not insist on the numerous theoretical difficulties of this idea. I will only point out that this "spark of divinity," which is supposed to distinguish the soul of man from that of the other animals, must be itself capable of development,

and has, as a matter of fact, progressively developed in the course of human history. As a rule, reason is taken to be this "spark of divinity," and is supposed to be an exclusive possession of humanity. But comparative psychology shows us that it is quite impossible to set up this barrier between man and the brutes. Either we take the word "reason" in the older sense, and then it is found in the higher mammals (ape, dog, elephant, having just as well as in man; or also in the narrower sense, and then it is lacking in most men just as much as in the majority of animals. On the whole, we may call any of man's reason what Goethe's *Mephistopheles* said:—

Let's name him better right among him
For the glow of heavenly light that
Then just goes him.
No souls it seems; thence his power's
Inward
To be still brighter than our best.

If, then, we must reject these popular and, in some respects, agreeable Dualistic theories as untenable, because inconsistent with the genetic facts, there remains only the opposite or historic conception, according to which the human soul is, like any other animal soul, a function of the central nervous system, and develops in inseparable connection therewith. We see this undeniably in every child. The tongueless *larva* attempts to utter its *pharyngeal* cry. Just as in every human embryo the *chorda* (not *notochord*) gives rise to the cordular tube, from the inferior end of which the five sacral vertebrae of the Cranium are developed, and from these the cerebral brain (but with the character of the lower, then with those of the higher *vertebrates*); and as the whole of this ontogenetic process is only a brief, hasty reproduction of the same process in the phylogenesis of the Vertebrates; as the wonderful spiritual life of the human race through many thousands of years has been evolved step by step from the lowly psychic life of the lower Vertebrates, and the development of every individual is only a brief repetition of that long and complex phylogenetic process. From all these facts must needs we conclude that the still prevalent belief in the immortality of the soul is an unscientific superstition. I have shown its inconsistency with modern science in the seventh chapter of *The Middle of the Chapter*.

Here it may also be well to point out

the great importance of anthropology, in the light of the biogenetic law, for the purpose of philosophy. The speculative philosophers who take cognizance of these anthropogenic facts, and explain them (in accordance with the law) physiologically, will advance the great questions of philosophy far more than the most distinguished thinkers of all ages have yet succeeded in doing. Most certainly every clear and consistent thinker must derive from the facts of comparative anatomy and ontogeny we have adduced a number of suggestive ideas that cannot fail to have an influence on the progress of philosophy. Nor can it be doubted that the careful statement and impartial appreciation of these facts will tend to the decisive triumph of the philosophic tendency that we call "Monistic" or "Mechanicism," as opposed to the "Dualistic" or "Teleological," on which most of the ancient, medieval, and modern systems of philosophy are based. The Monistic or Mechanistic philosophy affirms that all the phenomena of human life and of the rest of nature are ruled by fixed and unchangeable laws; that there is everywhere a necessary causal connection of phenomena; and that, therefore, the whole knowable universe is a harmonious unity, a system. It says, further, that all phenomena are due either to overabundance or efficient causes, and to final causes. It does not admit of a middle in the ordinary sense of the word. In the light of the Monistic philosophy the phenomena that we are wont to regard as the freest and most independent, the expressions of the human will, are subject just as much to rigid laws as any other natural phenomenon. As a matter of fact, impartial and thorough examination of our "free" will shows that they are never really free, but always determined by antecedent factors that can be traced to either heredity or adaptation. We cannot, therefore, admit the conventional distinction between nature and spirit. There is spirit everywhere in nature, and we have of no spirit outside of nature. Hence, also, the numerous methods of natural science and mental or moral science is untenable. Every action, as such, is both natural and mental. That is a few principles of Monism, which, on its religious side, we may also denominated Pantheism. Man is not above, but in, nature.

It is now that the opponents of dual-

ism have to reorganize the Monistic philosophy based on it as "Materialism," and confess the philosophic weakness of this union with a wholly unconnected and incompatible moral construction. Seriously speaking, it would be just as good to call our system Spiritualism as Materialism. The real Materialist's philosophy affirms that the phenomena of life are, like all other phenomena, effects or products of matter. The opposite extreme, the Spiritualist's philosophy, says, on the contrary, that matter is a product of energy, and that all material forms are produced by free and independent forces. Thus, according to one-sided Materialism, the matter is antecedent to the living form; according to the equally one-sided view of the Spiritualist, it is the reverse. Both views are Dualistic, and, in my opinion, both are false. For us the real double disappears in the Monistic philosophy, which knows neither matter without form nor form without matter. It is only necessary to subject for some days over the question from the strictly scientific point of view to see that it is impossible to form a clear idea of either hypothesis. As words used, "Matter can never exist or act without spirit, but spirit without matter."

The words "spirit" or "soul" is merely a force or form of energy, inseparably bound up with the material substratum of the body. The thinking force of the mind is just as much connected with the structural elements of the brain as the motor force of the muscles with their structural elements. Our mental powers and functions of the brain as much as any other force is a function of a material body. We know of no matter that is devoid of force, and no form that are not bound up with matter. When the forces enter into the phenomenon as movements we call them living or active forces. When they are in a state of rest or equilibrium we call them inert or potential. This applies equally to magnetic and organic bodies. The organic fluid carries iron filings, the powder that explodes, the steam that drives the locomotives, are living organisms. They are by living forces as much as the inertest liquid from which a candle is taken at night, or the concrete Amphibian that buries itself in the mud of the sea, or even when he sleeps. Only in the latter cases the combination of the different forces that appear as "movement" in the

phenomena are much more intimate and difficult to analyze than in the former.

Our study has led us to the conclusion that in the whole evolution of man, as in physiology and in his phylogeny, there is no living force at work other than that of the use of organic and inorganic matter. All the forces that are operative in it could be reduced to the stimulus, analysis or growth, the fundamental evolutionary function that brings about in terms of both the organic and the inorganic. But growth itself depends on the attraction and repulsion of homogeneity and heterogeneity particles. Seventy-five years ago Carl Kraus and four students laid the general basis of his thesis studies of animal development on the sentence: "The evolution of the individual is the history of the growth of individuality in every respect." And if we go deeper to the root of this law of growth, we find that in the long run it can always be reduced to that attraction and repulsion of associated atoms which Empedocles called the "love and hatred" of the elements.

Thus the evolution of man is directed by the same "eternal, iron law" as the development of any other body. There were always laid us back to the same simple principles, the elementary gravitation of physics and chemistry. The various phenomena of nature only differ in the degree of complexity to which the different forces work together. Each single process of adaptation and heredity in the development of our ancestors is in itself a very complex physiological phenomenon. For every individual are the processes of human embryology, in them are condensed and compressed thousands of the physiological processes.

In my *General Morphology*, which appeared in 1916, I made the first attempt to apply the theory of evolution, as outlined by Darwin, to the whole province of biology, and especially to provide with its foundations a mechanical foundation for the science of organic forms. The stimulus relates that exist between all parts of organic nature, especially the direct causal action between the two entities of evolution—ontology and phylogeny—were explained in that work for the first time by transformation, and were interpreted philosophically in the light of the theory of atoms. The morphological part of the *General Morphology* (first vol.) contains the first attempt to

determine the series of man's anatomy (vol. 5, p. 448). Moreover important this concept has, it provided a starting-point for further investigation. In the thirty-seven years that have since elapsed the biological sciences has been enormously widened, our empirical acquisitions in paleontology, comparative anatomy, and embryology have grown to an astonishing extent, thanks to the united efforts of a number of able workers and the employment of newer methods. Many important biological questions that then appeared to be obscure enigmas seem to be slowly united. Disruption across the above of a new day of pure scientific science after the dark night of mystic dogmatism, and we can see now, clearly and fully, that there is daylight in our field of inquiry.

Philosophers and others, who are equally ignorant of the empirical results of our science and the physiological methods of studying it, have even lately claimed that in the matter of man's origin and genealogical was nothing more had been done than the discovery of a "gallery of ancestors," such as we had in the questions of the Achilleus. This would be quite true if the genealogy given in the second part of this work were merely the juxtaposition of a series of actual forms, of which we gathered the generic impression from their external physiological resemblance. As we have sufficiently proved already, it is far up a question of a quite different thing—of the transformation and historical proof of the physiological constitution of their ancestors on the basis of their identity in internal structure and underlying development; and I think I have sufficiently shown in the first part of this work how far this is advanced to reveal to us their inner nature and its historical development. I use the words of no significance probably in the word of historical connection. I am one of those scientists who believe in a real "natural history," and who think as much of an historical knowledge of the past as of an exact investigation of the present. The incalculable value of the historical sciences cannot be sufficiently emphasized at a time when historical sciences are ignored and neglected, and where an "exact" science, so designated as it is narrow, would substitute for it physical experiments and mathematical formulae. Historical knowledge cannot be replaced by any other branch of science.

It is clear that the prejudices that stand in the way of a general recognition of this "natural anthropogeny" are still very great; otherwise the long struggle of philosophic systems would have ended in favour of Monism. But we may confidently expect that a more general acquaintance with the genetic facts will gradually destroy these prejudices, and lead to the triumph of the natural conception of "man's place in nature." When we hear it said, in face of this expectation, that this would lead to retrogression in the intellectual and moral development of mankind, I cannot refrain from saying that, in my opinion, it will be just the reverse; that it will promote

to an enormous extent the advance of the human mind. All progress in our knowledge of truth means an advance in the higher cultivation of the human intelligence; and all progress in its application to practical life implies a corresponding improvement of morality. The worst enemies of the human race—ignorance and superstition—can only be vanquished by truth and reason. In any case, I hope and desire to have convinced the reader of these chapters that the true scientific comprehension of the human frame can only be attained in the way that we recognise to be the sole sound and effective one in organic science generally—namely, the way of Evolution.

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